केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

HAMIRPUR DISTRICT, UTTAR PRADESH

उत्तरी क्षेत्र, लखनऊ

Northern Region, Lucknow

AQUIFER MAPPING AND MANAGEMENT PLANS OF

HAMIRPUR DISTRICT, UTTAR PRADESH STATE

CONTRIBUTORS

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DISTRICT AT A GLANCE

1		**GENERAL INFORMATION**		
	i	**Geographical area (km^2)**	**:**	4,021
	ii	**Administrative divisions**		
	a	No. of Tehsils	**:**	4
	b	No. of Blocks	**:**	7
	c	No. of Towns and urban areas	**:**	7
	d	No. of villages	**:**	497
	iii	**Population (as per 2011 census)**		
	a	No. of Males	**:**	5,93,537
	b	No. of Females	**:**	5,10,748
	c	Population density (People per km^2)	**:**	275
	d	Urban population	**:**	2,09,848
	e	Rural population	**:**	8,94,437
	iv	**Literacy Rate (as per 2011 census)**	**:**	68.80%
	v	**Per Capita net income (at current prices)**	**:**	₹ 54,698 (2016-17)
	vi	Climate	**:**	Sub – tropical temperate
	a	Normal Annual precipitation (2018)	**:**	685 mm
	b	Minimum temperature (°C)	**:**	4.6
	c	Maximum temperature (°C)	**:**	45.6
2		**GEOMORPHOLOGY**		
	i	**Major Physiographic units**	**:**	(i)Pre-Cambrian Bundelkhand massif as the basement. (ii)Quaternary alluvium comprising sands, clay and silt.
	ii	**Major Drainage**	**:**	Two major rivers, namely Yamuna and Betwa meet in the north-eastern part of the district. Dhasan river flows along north-west part of the

				district.
3		**Land Use [Ha]**		
	i	**Forest Land**	**:**	24,015
	ii	**Fallow Land**	**:**	8,084
	iii	**Gross Area sown**	**:**	3,40,489
	iv	**Net Area sown**	**:**	2,58,614
	v	**Gross Area irrigated**	**:**	1,61,757
	vi	**Net Area irrigated**	**:**	1,57,299
4		**Major Soil types**	**:**	Loam, Clay and Silt.
5		**Area under Principal crops [Ha]**		
	i	**Rabi**	**:**	1,68,704.80
	ii	**Kharif**	**:**	62,449.77
	iii	**Zaid**	**:**	9,664.70
6		**Sources of irrigation [2015-16]**		
	i	**Irrigation potential of dug wells [Ha]**	**:**	0
	ii	**Irrigation potential of Tube wells [Ha]**	**:**	19,450 (Government)
			:	1,12,101 (Private)
	iii	**Canals [Ha]**	**:**	6,153
	iv	**Other sources [Ha]**	**:**	19,525
7		**No. of CGWB GW monitoring stations [2019]**		
	i	**No. of Dug wells**	**:**	13
	ii	**No. of Piezometers**	**:**	02
8		**Hydrogeology and Aquifer Group**		
	a	**Major Water bearing formation**	**:**	Quaternary alluvium
	b	**Pre-monsoon depth-to-water level [May 2019]**	**:**	5.66 to 23.69 mbgl
	c	**Post-monsoon depth-to-water level [November 2019]**	**:**	3.77 to 23.13 mbgl
	d	**Decadal water level trend [2010 – 2019]**	**:**	Rise (cm) = 26.63
				Fall (cm) = 20.64

9		**Groundwater exploration by CGWB**		
	a	**No. of wells drilled**	**:**	EW = 21
				OW = 4
				PZ = 0
				SH = 2
	b	**Depth range (mbgl)**	**:**	74.74 to 200.00
	c	**Discharge (lpm)**	**:**	104 to 2994
	d	**Storativity (S)**	**:**	$1.25*10^{-3}$ to $7.90*10^{-4}$
	e	**Transmissivity (m^2/day)**	**:**	542 to 4107
10		**Ground water quality**		
	a	**Major Hydrochemical facies**	**:**	Mainly $Mg-HCO_3$
	b	**Presence of Trace metals**	**:**	Iron, Manganese and Zinc at few locations in unconfined aquifer.
11		**Dynamic Groundwater Resources [as per GEC-2015] (in Ham)**		
	a	**Annual Extractable Groundwater Resource**	**:**	42944.22
	b	**Current Annual Groundwater Extraction**	**:**	30940.61
	c	**Annual Groundwater allocation for domestic use as on 2025**	**:**	3056.95
	d	**Stage of Groundwater Development**	**:**	72.05%
12		**Awareness and Training activity**		
	i	**Mass Awareness programmes organized**	**:**	None
13		**Artificial Recharge and Rainwater harvesting Projects implemented**		
	a	**Projects completed by CGWB (₹)**	**:**	0
	b	**Projects under technical guidance of CGWB (Nos.)**	**:**	0
14		**Groundwater Control and Regulation**		
	a	**No. of over-exploited blocks**	**:**	0
	b	**No. of critical blocks**	**:**	0

	c	**No. of semi-critical blocks**	**:**	5
	d	**No. of notified blocks**	**:**	2
15		**Major Groundwater issues and problems**	**:**	(i) Thin granular zones. (ii) Over-use of groundwater, mainly for irrigation. (iii) Erratic rainfall with prolonged droughts. (iv) High Fluoride and Salinity in patches.

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1. INTRODUCTION

1.1 Objectives and Scope:

Considering the existing issues of ground water over-exploitation, contamination and other related issues, Central Ground Water Board under MoWR, RD & GR has embarked upon the new initiative of Aquifer Mapping and Management Programme. The programme was initiated under Ground Water Management and Regulation Plan Scheme of XII plan. Major objectives of the programme are

- Delineation and characterization of aquifers in three dimensions
- Identification and quantification of issues
- Development of management plans to ensure sustainability of ground water resources.

Under the initiative, management plans for each aquifer system are being prepared suggesting various interventions to optimize ground water withdrawal and identifying aquifers with portable groundwater for drinking purpose in quality affected areas. The management options also include identification of feasible area for artificial recharge to ground water and water conservation which help in arresting declining water levels besides demand side management option including crop diversification, increasing water use efficiency etc [1].

1.2 Approach and Methodology :

A multidisciplinary approach using advanced tools and techniques including remote sensing, GIS, geophysical techniques, ground water modelling etc. is being followed for preparation of aquifer maps and development of management plans.

A multi-tier evaluation process has been put in place to ensure quality of outputs. The aquifer maps and management plans prepared by the team of officers are reviewed by the Regional Directors of the respective regions of CGWB. The revised maps and management plans are later presented before the concerned members of CGWB at the central headquarters level. Subsequently the maps and management plans are presented before the National level expert committee (NLEC) constituted for this purpose. Domain specialists, who are part of the expert committee, include ground water specialists from JNU, Delhi; IIT, Roorkee; retired Chairman of CGWB; Agriculture Scientists etc. Agriculture scientists of ICAR have also been associated in finalization of management plans for each State. In order to coordinate on various issues related to aquifer mapping, between the State and Union Government, State Ground Water Coordination Committee (SGWCC) has been formed in each state and UT, headed by the principal secretary of the concerned department. The outputs are shared and deliberated in State Ground Water Coordination Committee with an objective to have mutual agreement on the proposed aquifer-wise ground water management plans which can be implemented by State Government [2].

The flow chart of the methodology is given below in Figure 1 -

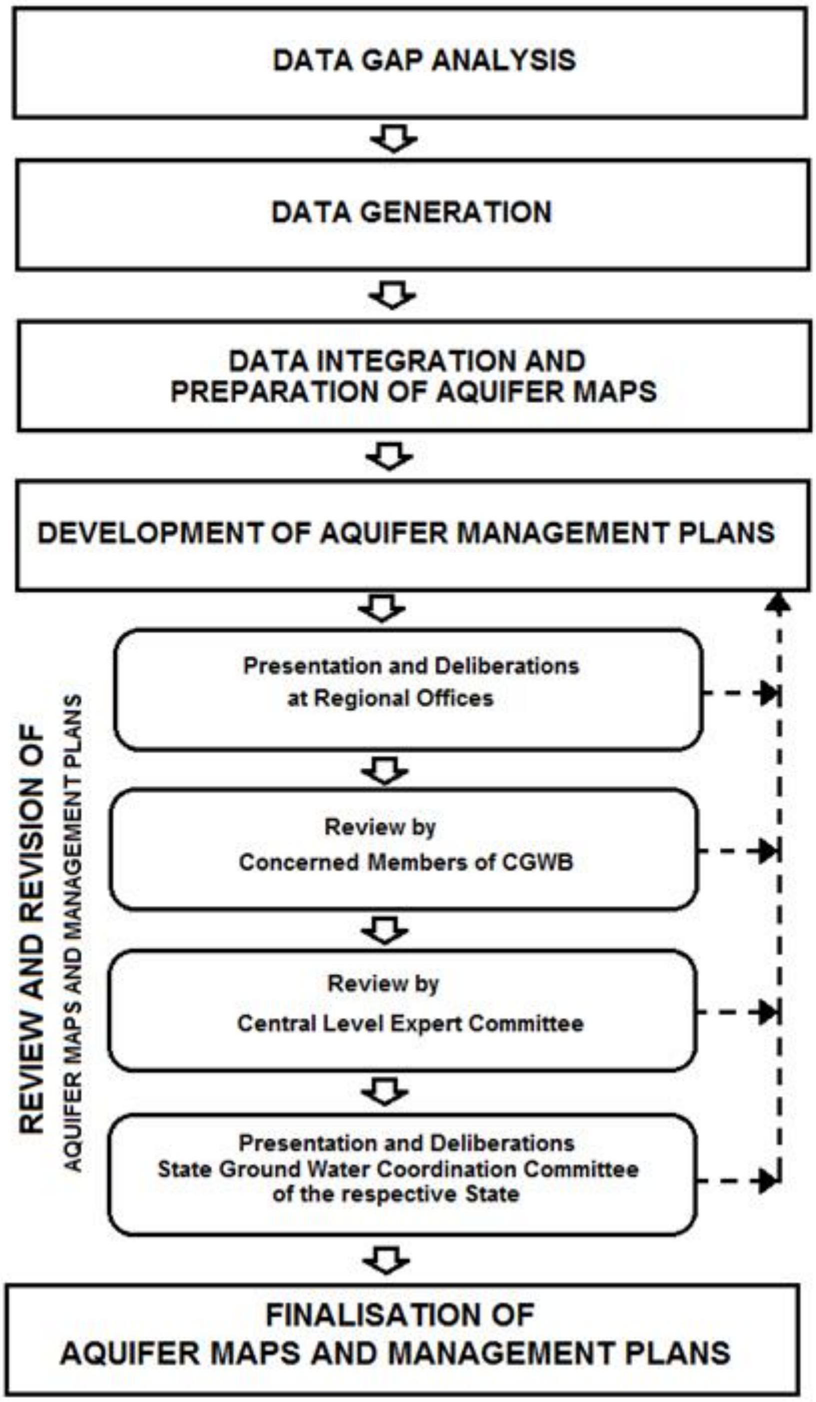

Figure 1: Methodology of NAQUIM

1.3 Study Area:

The district is a land-locked district situated in the dry southern portion of Uttar Pradesh state known as Bundelkhand. It lies between the latitudes 25°27’00”N to 25°57’00”N and longitudes 79°11’00”E to 80°19’00”E. It is a part of Chitrakoot Dham Division of Uttar Pradesh state with Hamirpur town as the district headquarters. It connects the central portion of Uttar Pradesh known as Awadh to Bundelkhand. It is bounded by Kanpur and Fatehpur districts to the north, Banda district to the east, Mahoba district to the south and the districts of Jhansi and Jalaun to the west.

As per 2011 census, it is the 3rd least populous district of Uttar Pradesh state and is the confluence point for 2 rivers, Yamuna and Betwa in the north-eastern part of the district. Coarse sand mined from the banks of the Betwa river is exported to various parts of Uttar Pradesh state [3].

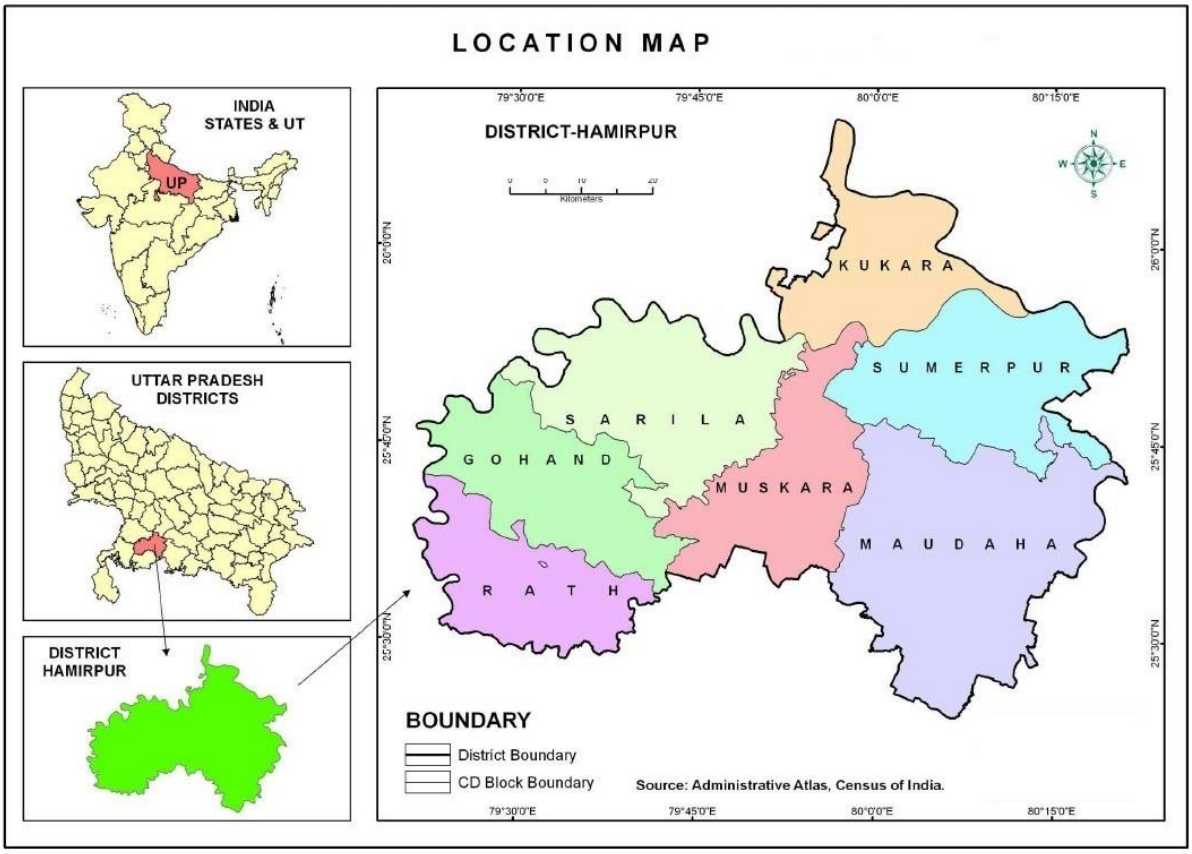

Figure 2: Location map of the study area

1.4 Climate and Rainfall:

The climate of the study area is classified as sub-tropical temperate. It is categorized as '**Cwa**' according to **Köppen–Geiger climate classification system [4].**

- The first letter '**C**' indicates that the area has temperate climate .i.e average temperature in the winter is above 0°C but below 18°C.
- The second letter '**w**' denotes at majority of the rainfall is received from the monsoon operating over the area and the area is characterized by dry winter, wherein minimal precipitation takes place in winter.
- The third letter '**a**' indicates the degree of summer heat where the warmest monthly average temperature is above 22°C.

Cwa = Monsoon-influenced humid subtropical climate; coldest month averaging above 0 °C (32 °F) (or −3 °C (27 °F)), at least one month's average temperature above 22 °C (71.6 °F), and at least four months averaging above 10 °C (50 °F). At least ten times as much rain in the wettest month of summer as in the driest month of winter (alternative definition is 70% or more of average annual precipitation is received in the warmest six months).

<u>Rainfall</u> – The precipitation data for Hamipur district for the period 1971-2019 was obtained from satellites operated by European Space Agency and is represented below in the form of a graph. Data has been attached under Annexure 1 –

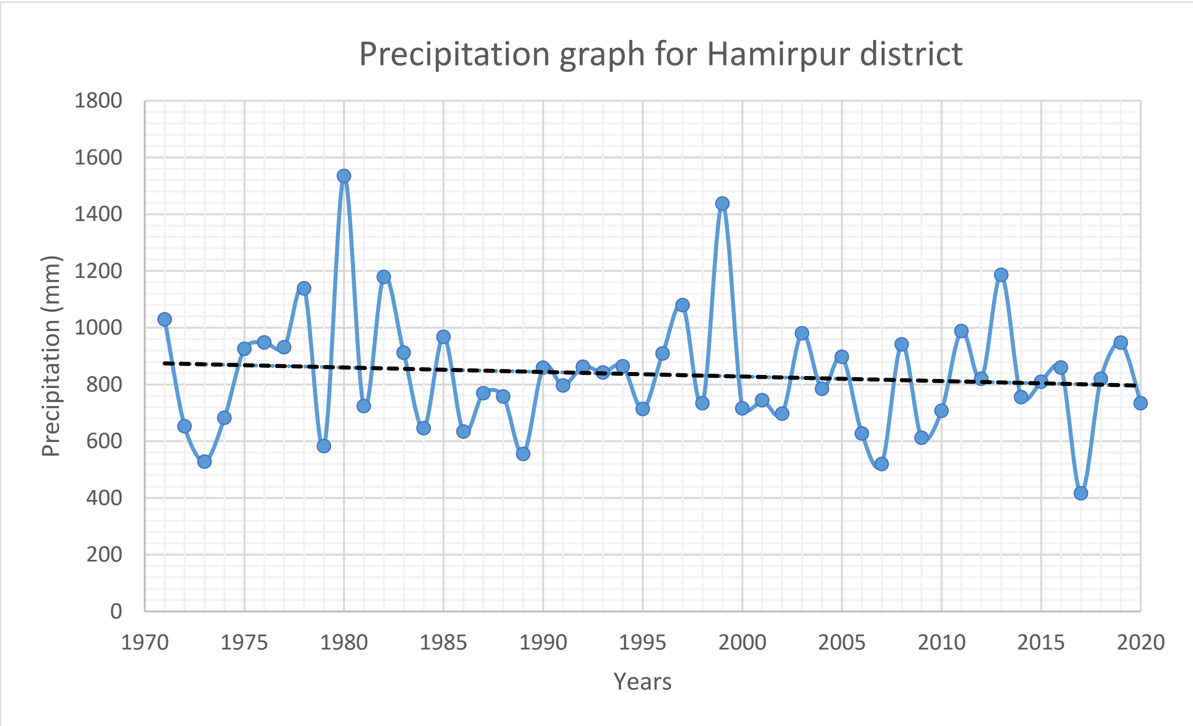

Figure 3: Precipitation graph of Hamirpur district [1971-2019]

1.5 Geology and Geomorphology:

Geographically the area comprises Bundelkhand granite gneiss complex and recent alluvium. The thickness of alluvium varies from 120 to 150 meters. The master slope of district is due northeast. The district could be broadly divided into two physiographic regions.

1. The southern part of district is mainly plain area with average elevation of 250 mamsl. The region is underlain by thin alluvial cover.

2. The northern part of district represents flat topography. The average elevation of the region 120mamsl.

The district chiefly constitutes drainage basin of river Betwa and Ken which are two important right bank tributaries of river Yamuna, river Dharsan also drains major western part of district. The rivers presemt in the district are Yamuna, Betwa, Dhasaan, Barma, Ken, Chandraval and Pandwaha.

The district can be divided into two topographical units.

I. Recent Alluvial Plain: The area occupied by the recent alluvium can be delineated all along Betwa and Ken River.

II.Bundelkhand Granite Gneiss:The isolated, remanent hillocks represent topography of the regions.

The district comes under the doab region of Ken and Betwa covered by the recent alluvium, the development of soil in the district can be ascribed to different erosion and depositional agencies. Depending upon the morphological units of the district, the soil ranges from pure to stiff clay and includes all combinations of the two extreme litho units. The pure sand is called Bhur and clay is called Matiar. Along the Yamuna valley, the red alluvium is overlain by grey alluvium. The geographical age of red alluvium up to 500 m below ground level is almost 119 thousand years, whereas age of grey alluvium up to the depth of 25 m is 82,000 years. Alluvium of Yamuna is up to a thousand year old.

The terrain of Hamirpur situated in the Peninsular Shield, is differentiated into a rocky surface of Bundelkhand highland and alluvium surface of Ganga Plain. The rocky surface, attaining elevations of 225 to 335m, contains pediment and dissected denudational hills, The Ganga Plain, with elevation of 110 to 250 m in the northern part, consists of upland and lowland. Banda Plain and Varanasi Plain constitute upland. Banda Plain is rolling with inselbergs and is sandy to gravelly, whereas Varanasi Plain is flat and silty in nature. The lowland is 10 is 30m lower than the upland. It is developed along Yamuna, Betwa and Dhasan rivers and comprises Older Flood Plain and Active Flood Plain. Two levels of terraces are developed along Yamuna and Betwa rivers. The lower terrace (T1) is depositional which preserves sediments deposited by present rivers during their process of incision. The terrace (T2) occurring at higher level is erosional in nature. River bed and flood plain make Channel Plain which is sandy to gravelly in general. Gully erosion resulting in badland formation (2 to 5 km wide) is a major natural hazard. Bank erosion is commonly seen along Yamuna, Betwa and Dhasan rivers. The district lies in Seismic Zone I and II [5].

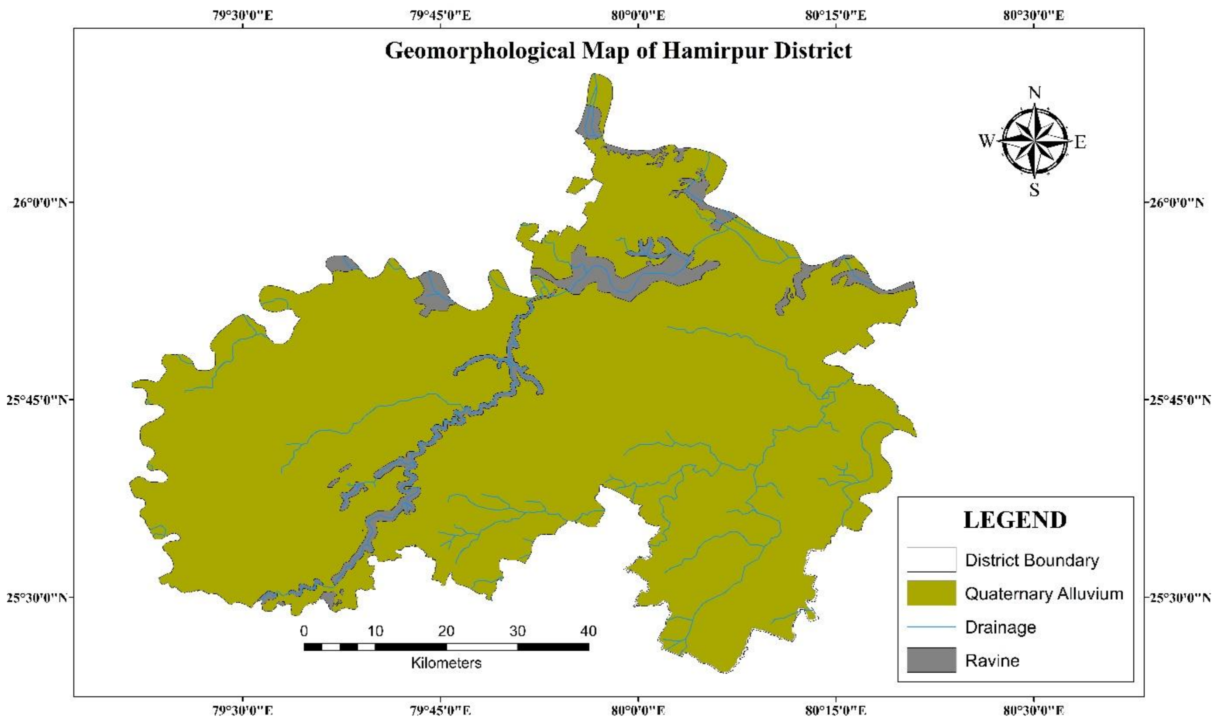

Figure 4: Geomorphological map of Hamirpur district

Geology

Geologically, the area of Hamirpur is broadly divisible into Bundelkhand Granitic Complex (BGC) consisting of rocky of Archean–Proterozoic period and non-lithified sediments of Quaternary period.

The district comprises a portion of the Bundelkhand plateau region which is underlain by Granites and basic intrusive rocks. Non-lithified alluvium comprising sand, silt and clay overlies the Granitic basement. The alluvium and basement are separated by an unconformity that represents a period of non-deposition. The thickness of alluvium decreases from >150.00 mbgl at Kurara block in the north to <20.00 mbgl at Maudaha block in the south. The Geological sequence of the district has been tabulated below.

Age	Formation	Lithology
Quaternary	Alluvium	Sand, silt and clay
--UNCONFORMITY---------------------------------------		
Precambrian		Granite

Table 1: Geological succession of Hamirpur district

The Quaternary sediments present in parts of Prayagraj (erstwhile Allahabad), Banda, Hamirpur, Fatehpur, Pratapgrah and Rae Bareli districts of Uttar Pradesh state have been classified into Banda Older Alluvium (BOA), Varanasi Older Alluvium (VOA) and Newer /Younger Alluvium. Banda Alluvium and Varanasi Alluvium are of Pleistocene period and represent Older Alluvium. Each represent a cycle of sequence of deposition in basins of different configuration at different periods.

The Banda Older Alluvium (BOA) represents the first cycle of Quaternary sedimentation whose provenance lies in Peninsular terrain and has been sub-divided into basal variegated clays and an upper Chitrakoot Formation. It contains oxidized sediments (Brown, yellow and khaki coloured) along with with kankar, red quartzo-feldspathic sand and gravel.

The Varanasi Older Alluvium (VOA) constitutes the second cycle of sedimentation and comprises polycyclic sequence of micaceous sand, silt and clay with kankar. Its provenance has been identified as belonging to extra-peninsular origin.

The Newer Alluvium comprises the third cycle of sedimentation and has been sub-divided into Terrace Alluvium and Recent Alluvium. It is largely confined to the palaeobanks of the rivers and contains non-oxidized sediments (Grey and khaki coloured).

Terrace Alluvium consisting of 8 to 15 m thick sequence of sand, silt and clay, occupies terraces of Yamuna and Betwa rivers.

Loose sand of point and channel bars constitutes Channel Alluvium of Yamuna and Betwa rivers [6].

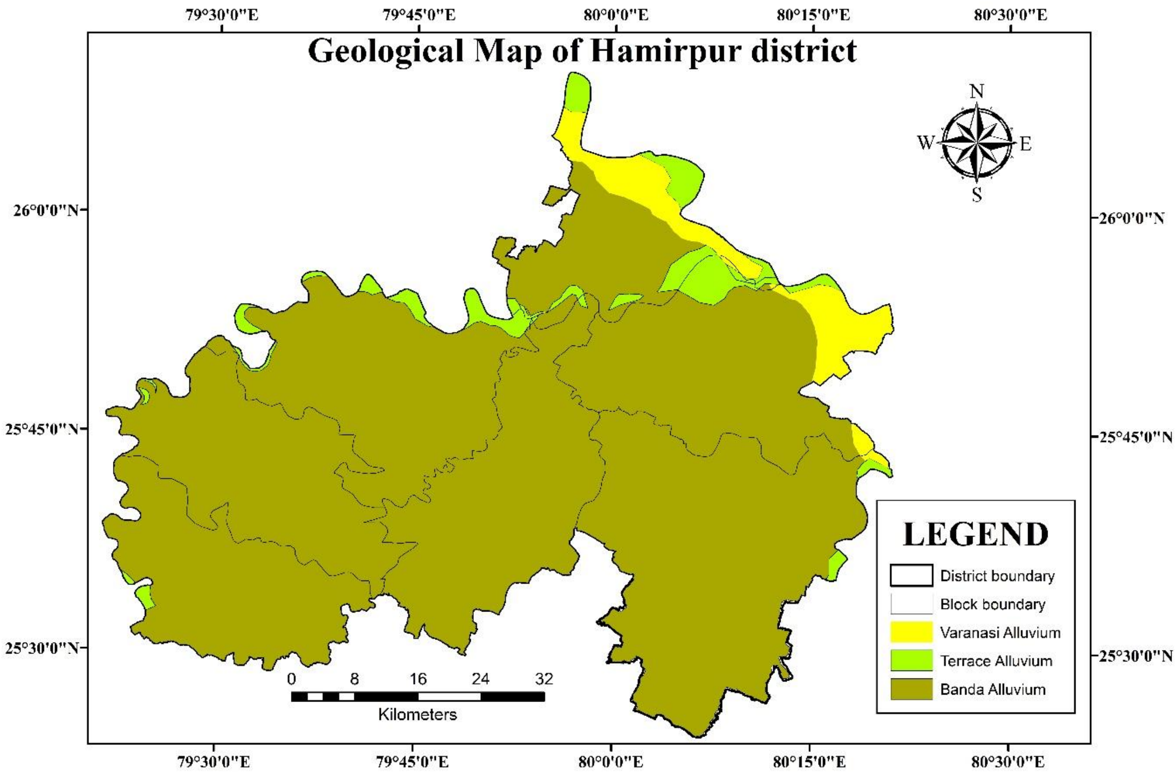

Figure 5: Geological Map of Hamirpur district

1.6 Soil, Land use, Irrigation and Cropping pattern:

1.6.1 Soil

The soil profile comprises 9 types of different soils in the district and are described briefly below:

1. Coarse loamy calcareous soil – Loamy soil is characterised by the presence of 40% sand (particle size>63µm), 40% silt (particle size>2µm) and 20% clay (particle size<2µm). As per USDA classification, soil that isn't predominantly sand, silt or clay is loam. They contain more humus, nutrients and moisture compared to sandy soils; have better drainage and are suitable for most plant varieties [7]. Calcareous content varies from 1-40% [7]. Texture of soil is coarse grained. The soil is seen in the western fringes of Sarila block and northern parts of Gohand block.
2. Fine calcareous soil – Calcareous content varies from 1-40% [8]. Texture of soil is fine grained. Soils are alkaline in nature, ranging from 7-10. They also contain significant amount of Iron, Aluminium and Manganese either as discrete minerals, coating on soil particles or complexed with organic matter. They are generally found in semi-arid to arid regions with low precipitation. The soil is seen deposited along the courses of the rivers Yamuna, Betwa and Virma in north-eastern part of Rath block, parts of Muskara and Sarila blocks; major portions of Sumerpur and Kurara blocks in addition to eastern part of Maudaha block.
3. Fine loamy soil – Composition is similar to coarse loamy soils but the texture is fine grained. It is considered ideal for gardening and agricultural uses because it retains nutrients well and retains water while still allowing excess water to drain away [9]. The soil is deposited in west, central and north-eastern part of Rath block extending into south-central and eastern part of Gohand block terminating in south-central part of Sarila block. Some portion is also seen in north-west part of Gohand block, north-central part of Sarila block; parts of Kurara block in addition to west-central portion of Maudaha block.
4. Fine loamy calcareous soil – It is a mixture of loam and calcareous types. Texture of soil is fine grained. pH varies from 7.0 – 8.5 and carbonic acid maybe formed with sufficient rainfall leading to decrease in soil pH. The soil is seen as patches in central and south-central portion of Sumerpur block in addition to eastern parts of Maudaha block.
5. Fine Montmorillonitic soil – Montmorillonite is a type of clay and is a sub-class of Smectite group. The individual crystals of montmorillonite clay are not tightly bound hence water can intervene, causing the clay to swell. The water content of montmorillonite is variable and it increases greatly in volume when it absorbs water. It is known to adsorb heavy metals and is of concern for human health [10]. Particle size is <2µm. The soil is seen in the north-west-central part of Rath block extending into central part of Gohand block and central and north-eastern part of Sarila block. Minor patches seen in southern part of Muskara block and south-western parts of Maudaha block.
6. Fine Montmorillonitic calcareous soil – This soil type is a mixture of clays and $CaCO_3$ deposits (1-40%). Texture is fine grained due to higher clay content compared to $CaCO_3$ amount. The soil is seen in central part of Rath block extending into south-eastern and central part of Gohand block and south-west, northern and central parts of

Sarila block. It is also seen in parts of Muskara, Kurara, Sumerpur and Maudaha blocks.

7. Fine silty soil – This soil type with particle size intermediate between that of sand and clay (63-2µm). It originates from weathering of Quartz and Feldspars, through chemical weathering and physical weathering processes like haloclasty, fluvial comminution and aeolian attrition etc. Silt is easily transported in water or other liquid and is fine enough to be carried long distances by air in the form of dust. It is usually found in semi-arid environments [11].
8. Fine silty calcareous soil – It is a mixture of silt and $CaCO_3$ deposits (1-40%). Texture is fine grained due to higher silt content compared to $CaCO_3$ amount. The soil is restricted to the border of Sumerpur and Muskara blocks.
9. Loamy skeletal soil – They are soils containing 35% or more (by volume) of rock fragments, cobbles, gravel, and laterite concretions or ironstones having diameters >2mm, within shallow depths (less than 50 cm). Soils shallow to bed rock or soils containing rock fragments are common in areas where the parent rocks are subjected to continuous erosion or weathering. They occupy mostly foothill slopes, mountains, and partial peneplains or erosional surfaces and are usually shallow, prone to erosion, and low in natural fertility status [12]. The soil is seen in central and southern parts of Rath block.

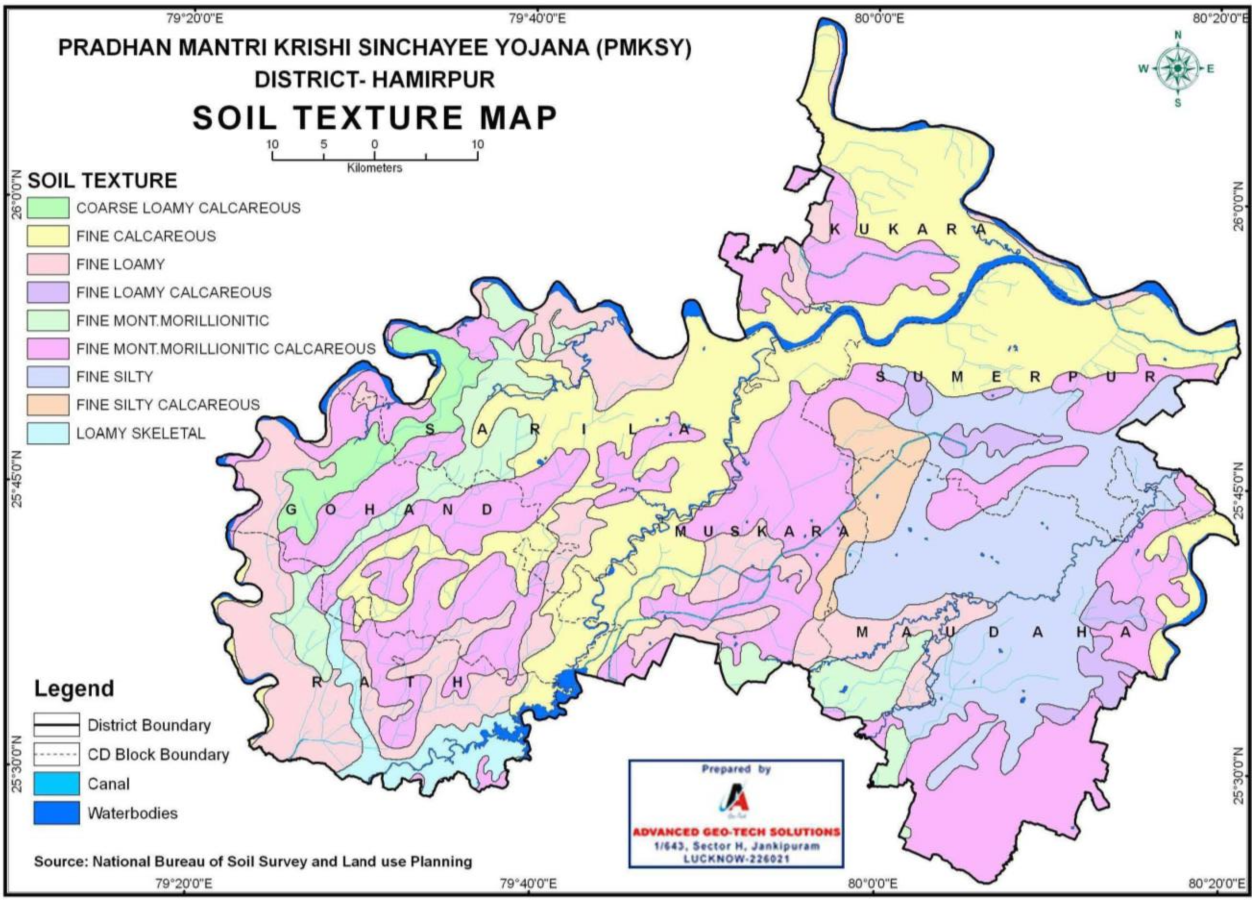

Figure 6: Soil texture map of Hamirpur district

1.6.2 Land Use and Land Cover

The Land use/Land cover details obtained from Bhuvan Portal, NRSC were integrated into a thematic map and analysed with reference to prevailing agricultural practices and other land uses. It is observed that the major part of the district is occupied by agricultural land.

Built up land is restricted to Block HQ and scattered towns.

Forest is seen as patches in parts of Rath, Muskara, Sarila, Maudaha and Kurara blocks. Grazing land is observed alongside agricultural land and is utilized for cattle grazing after harvesting season.

Ravines are seen along the banks of Virma, Betwa and Yamuna rivers. The gullied/ravinous land is unsuitable for any productive use.

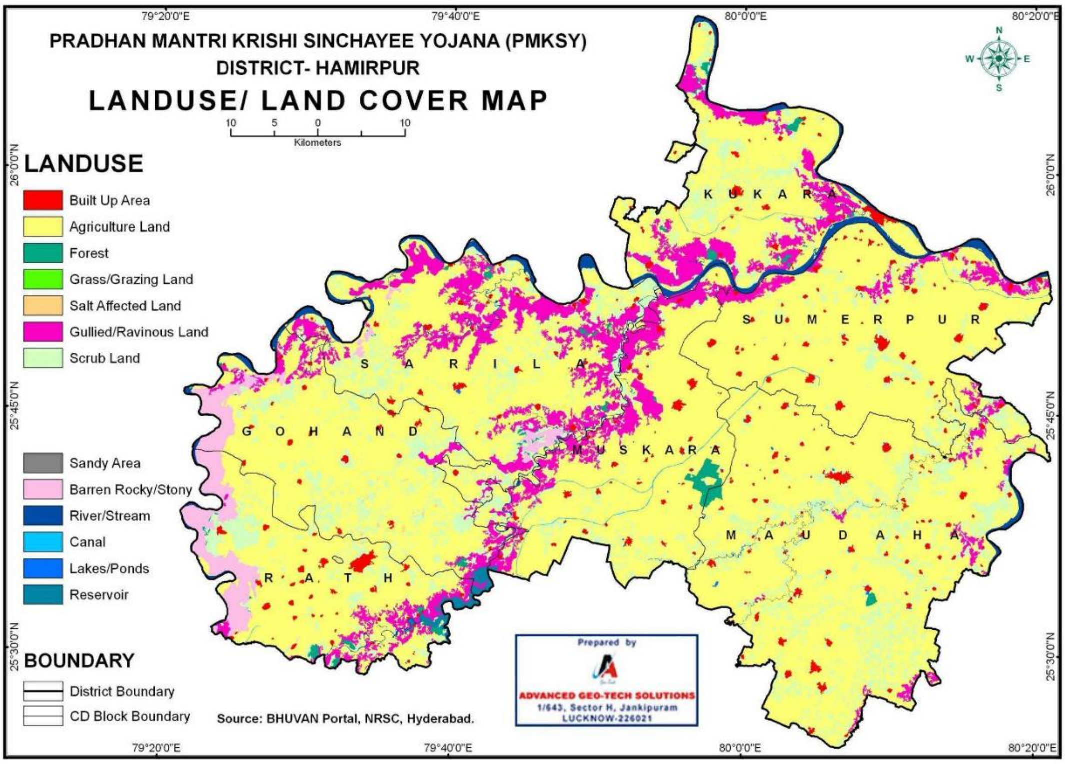

Figure 7: Land Use/Land cover map of Hamirpur district

1.6.3 Cropping pattern

The farmers in the district mainly practiced rainfed agriculture until the advent of canals. The construction of 11 major canal systems in addition to increasing use of electrical pump sets has enabled the farmers easy access to both surface and groundwater for irrigation purposes.

The major crops grown are Wheat, pea, oil seeds like mustard, sunflower, groundnuts, and lentils like pigeon pea (Arhar dal), red lentil (Masoor dal), black gram (Urad dal) etc and millets like sorghum (Jowar) and pearl millet (Bajra).

Seasonal vegetables are also grown based on quantum of water available for irrigation.

Kharif crops (autumn) cultivated are pearl millet, black gram, sorghum, green gram and rice.

Rabi crops (winter) cultivated are wheat, barley, peas, pigeon pea and red lentils.

Zaid crops (additional harvest) cultivated are melon, pumpkin, watermelon and bitter gourds [13].

The data has been summarized and been tabulated below.

Sl. No.	Type of Crop	Kharif Area (Ha)			Rabi Area (Ha)			Summer Crop (Ha)			Total Area (Ha)		
		Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
1	Cereals	31	11870.96	11901.96	99397	0	99397	37	0	37	99465	11870.96	111336
2	Coarse Cereals	0	36596.22	36596.22	0	21350.01	21350.01	0	0	0	0	57946.22	57946.22
3	Pulses	44	0	44	14244.3	0	14244.3	6100.2	0	6100.2	20388.5	0	20388.5
4	Oil Seeds	0	0	0	7798	0	7798	3527.5	0	3527.5	11325.5	0	11325.5
5	Fibre	0	0	0	0	0	0	0	0	0	0	0	0
6	Other crops	13907.6	0	13907.6	7143.4	18772.06	25915.46	0	0	0	21051	18772.06	39823.06
	TOTAL	13982.6	48467.17	62449.77	12858.7	40122.07	168704.8	9664.7	0	9664.7	152230	88589.24	240819.2

Table 2: Details of crops grown in Hamirpur district

1.7 Hydrology and Drainage of the study area:

The district chiefly is situated amidst drainage basins of the rivers Betwa and Ken which are two important right bank tributaries of river Yamuna, River Dhasan also drains major western part of district. A number of irrigation canals constitute source of surface water mainly utilized for irrigation purpose.

All rivers and rivulets flow north and north-east towards Yamuna river. The depositional environment has resulted in ravines. The main rivers are Yamuna, Betwa, Dhasan and Ken with numerous tributaries.

The upstream portion of streams with smaller channels have low but abrupt sides covered with low scrub. The downstream portion, they cut deeper beds much below the level of surroundings and the land becomes increasingly uneven and scoured. Occasional strips of fertile land is observed along the course.

(i) Yamuna: The river enters the district near the village of Hauralipur after which it takes the shape of a loop. This has resulted in a north-eastern part flowing approximately 56km long path. The stream is well below the level of southern bank forming an abrupt cliff in contrast to shelving northern bank, with minor exceptions. Ravines stretch inland from the cliffs carved out by rain.

(ii) Betwa; Flows along the north-western border of the district and separates Rath block from Jalaun district. The river enters the district near Beri village and separates Rath and Maudaha blocks from Hamirpur block. Total length of flow is 65kms long. Most of the river bed is sandy and the banks before joining Yamuna are free of ravines.

(iii) Dhasan: The river flows northward from Lahchura Ghat separating Hamirpur from Jhansi district. Upstream course is through rocks but downstream bed is sandy until it meets Betwa. River banks are eroded by ravines but less prominent in Hamirpur district.

(iv) Birma: It is a perennial stream and tributary of Betwa. It arises in the hilly tract west of Jaitpur in Mahoba district. The upper reaches are rocky and lie deep below the level of the surrounding tracts, but the watersheds terminate a few kilometres from the stream and very little land suffers the erosive action of its tributaries. Later, its tributaries become more frequent and form extensive ravines that invade the fertile plains of Muskara and Rath blocks and hardly compensate for the deterioration they cause by depositing patches of alluvial silt. Throughout its course, this stream is extremely tortuous.

(v) Ken: Enters the district at Khair village and flows 29kms north-eastward forming the boundary of Maudaha block with Banda district. There are no ravines along its bank, but it exercises important influence through its tributaries [14].

Drainage map of the district has been attached below as Figure 8.

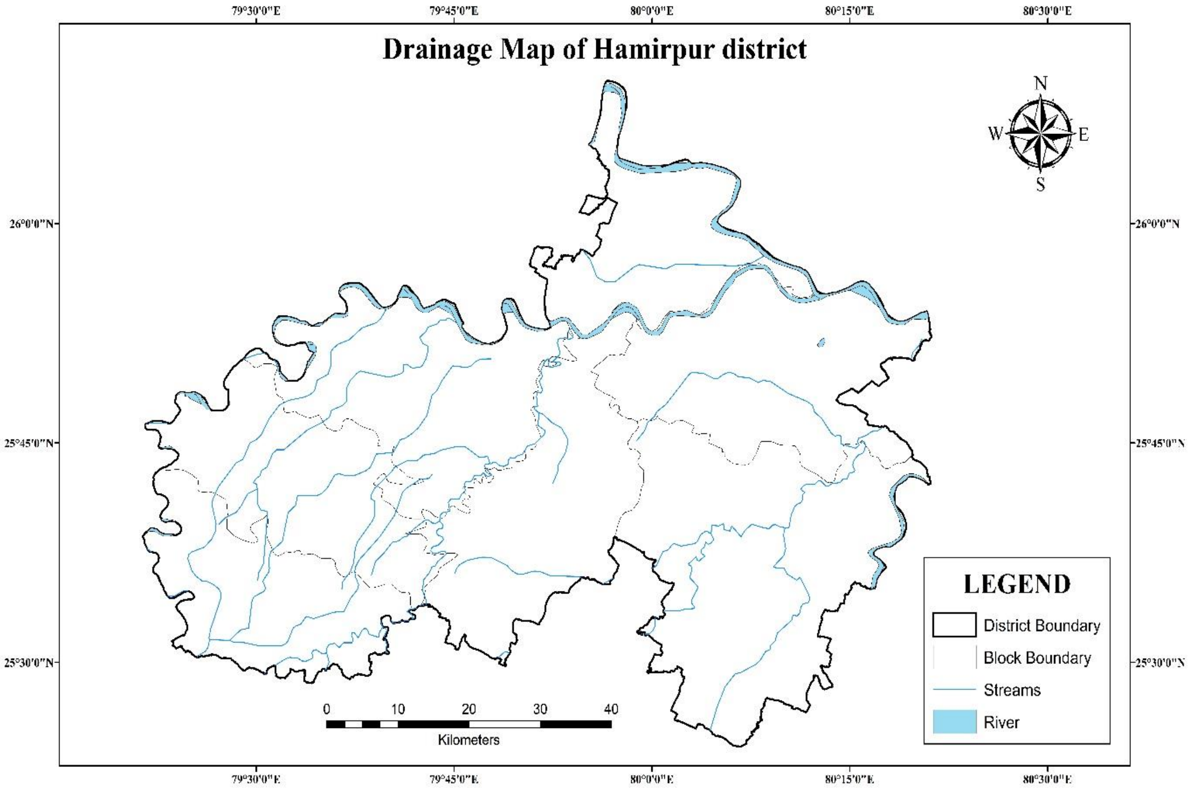

Figure 8: Darinage map of Hamirpur district

1.7.1 Riverine canal system:

The river canal system is prevalent in Kurara, Rath and Sarila blocks.

The canals are fed by dams, embankments, tanks and lakes covering Muskara and Maudaha blocks [14].

Sum total of 11 canals exist in Hamirpur district and the details have been summarized and tabulated in Table 3 below.

Sl. No.	Canal system	Source	Year of construction	Length (kms)	Areas Irrigated (Blocks/District)
1	Betwa	Parichha (Jhansi)	1887-88	58	Hamirpur
2	Dhasan	Lahchura	1912	632	Charkhari and Rath
3	Majhgawa	Tank	1914	52	
4	Kulpahar	Tank	1924	08	
5	Bela-Sagar	Tank	1924		
6	Raipura			110	
7	Kamalpura				
8	Arjun	Dam			Charkhari and Hamirpur
9	Kabrai				Mahoba and Maudaha
10	Keolari		1973-74	426	
11	Chandrawal	Dam			

Table 3: Details of dams in Hamirpur district

1.8 Prevailing Water Conservation and Recharge practices:

None

2. DATA COLLECTION, INTEGRATION AND AQUIFER MAPPING

2.1 Exploratory drilling

Based on available exploratory drilling data obtained from 3 Slim Holes and 20 Exploratory wells, the variation in lithology as well as ascertaining the depth at which bedrock (Bundelkhand Granite) is encountered was useful for demarcating aquifer groups and determining thickness of aquifer. The maps displaying location of Exploratory drilling sites in Hamirpur district and Depth to Basement map of Hamirpur district has been attached below as Figure 9 and Figure 10 respectively.

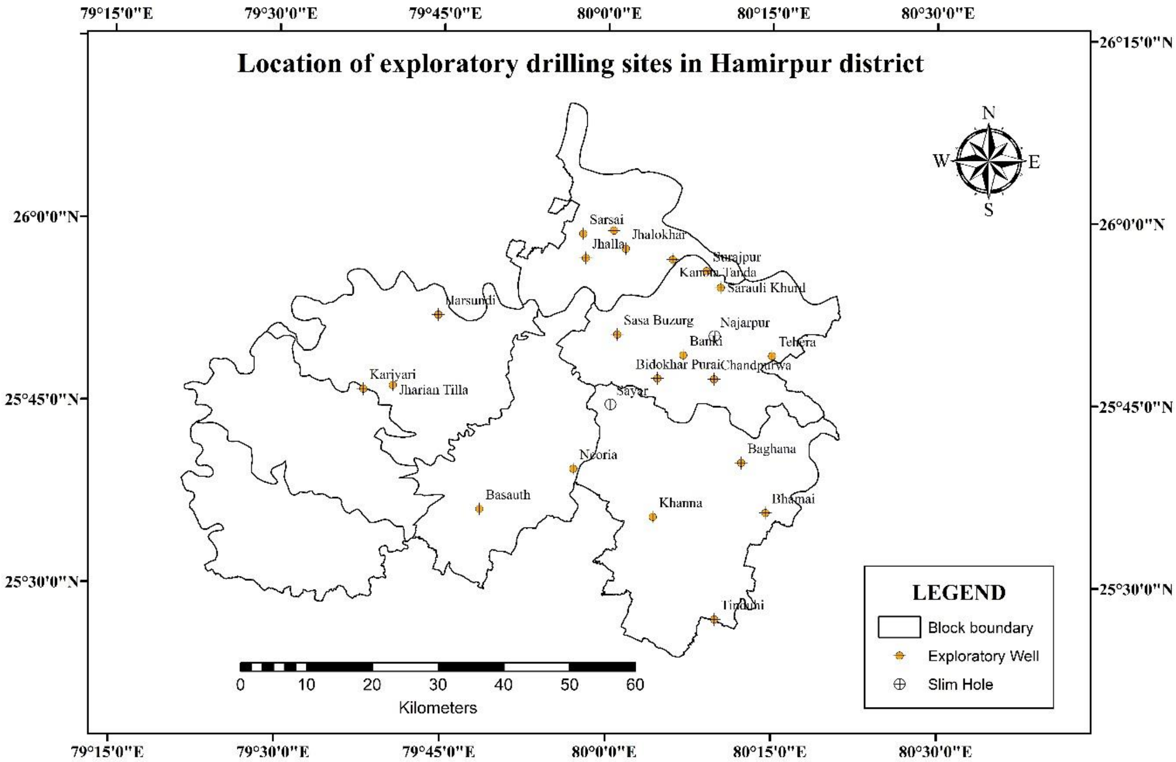

Figure 9: Location of exploratory drilling sites in Hamirpur district

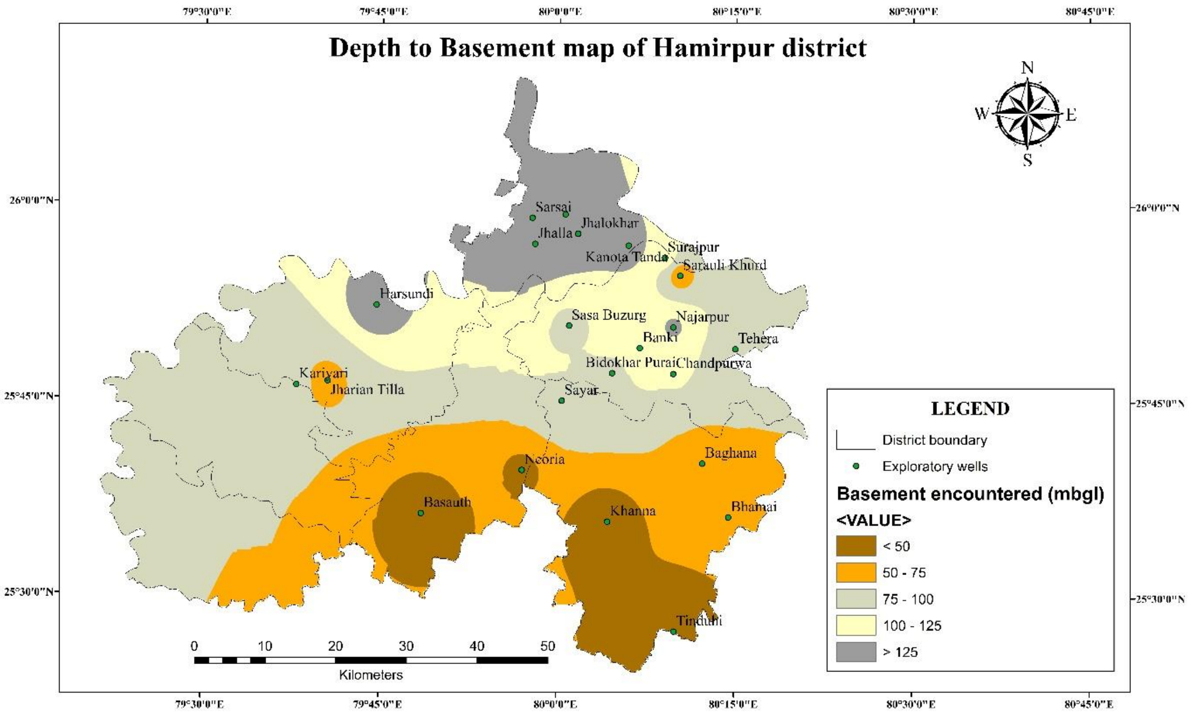

Figure 10: Depth to Basement map of Hamirpur district

A visual assessment of Depth to Basement map reveals the thickness of Quaternary alluvium increases northwards. Basement is encountered at shallow depths at the following places – Tinduhi (25 mbgl) and Khanna (30 mbgl) in Maudaha block in addition to Basauth (31 mbgl) in Muskara block. Other exploratory drilling sites reveal basement is encountered between the depths of 50 mbgl to 125 mbgl towards Betwa river in the northern portion of the district. Basement is encountered at deeper depths at Harsundi (134 mbgl) in Sarila block in addition to Jhalokhar (130 mbgl), Jhalla (132 mbgl), Kanota Tanda (134 mbgl) and Sarsai (140 mbgl) in Kurara block.

2.2. Groundwater quality

2.2.1 General aspects of unconfined aquifer

Phreatic aquifer is found between the depths of 20 – 60 mbgl (metres below ground level) and is tapped by dug wells and Indian Mk.II Hand pumps. The discharge ranges from 50 lpm to 150 lpm [15].

2.2.2 Groundwater sampling

Pre-monsoon sampling was carried out in June 2019 with respect to determination of basic parameters and trace metals and also with the intention to demarcate areas with spurious quality of groundwater. 54 groundwater samples were collected for analysis of trace metals whereas 161 samples were collected to determine basic parameters.

2.2.3 General Hydrogeochemistry of unconfined aquifer

160 samples collected during June 2019 to ascertain basic parameters were plotted on the trilinear Hill-Piper diagram [16] and the samples were classified into the following categories based on dominant cations and anions –

- 55% of samples lie on Mg^{2+}- HCO_3^- quadrant that indicate (Ca^{2+} + Mg^{2+}) > (Na^+ + K^+) and groundwater is shallow and fresh in nature,
- 19.375% of samples lie on Mixed type quadrant that indicate (Ca^{2+} + Mg^{2+}) + (CO_3^{2-} + HCO_3^-) > (Na^+ + K^+) + (Cl^- + SO_4^{2-}) and represents deep groundwater influenced by ion exchange,
- 15% of samples lie on Na^+ - HCO_3^- quadrant that indicate (Cl^- + SO_4^{2-}) > (CO_3^{2-} + HCO_3^-) and represents deep groundwater influenced by ion exchange,
- 10 % of samples lie on Na^+ - Cl^- quadrant that indicate (CO_3^{2-} + HCO_3^-) > (Cl^- + SO_4^{2-}) and represents marine, deep and ancient groundwater;
- 0.625% of samples lie on Ca^{2+} - Cl^- quadrant that indicate (Na^+ + K^+) > (Ca^{2+} + Mg^{2+}) and is representative of mine drainage.

The results of the chemical analyses have been attached as Annexures-2 and 3 respectively.

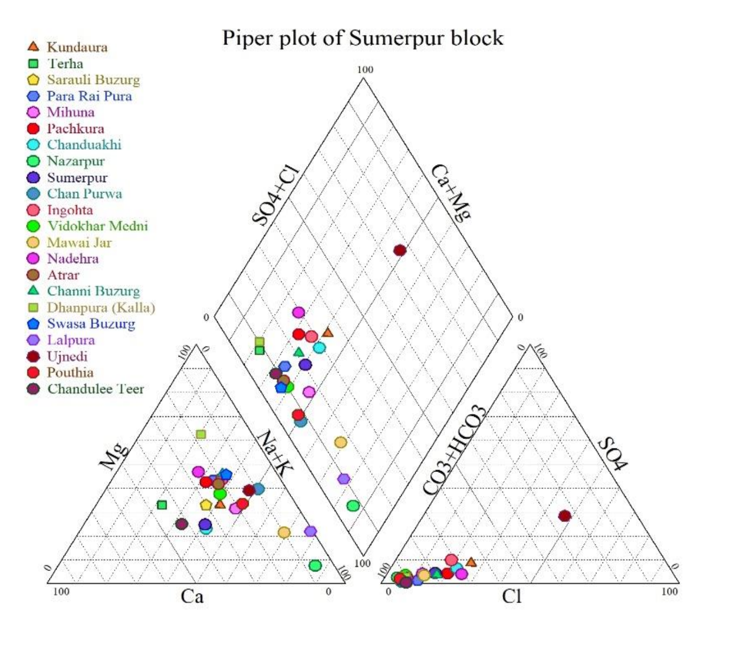

Figure (a): Piper plot of Sumerpur block

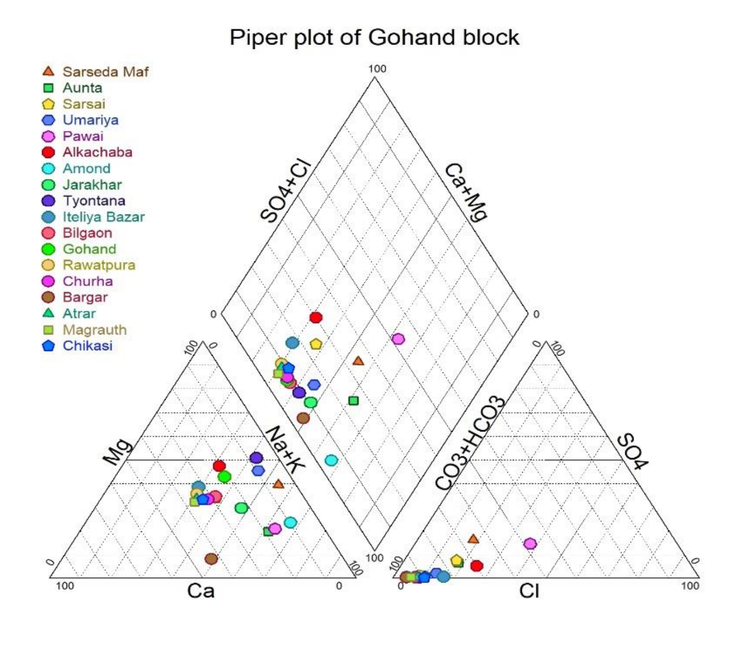

Figure (b): Piper plot of Gohand block

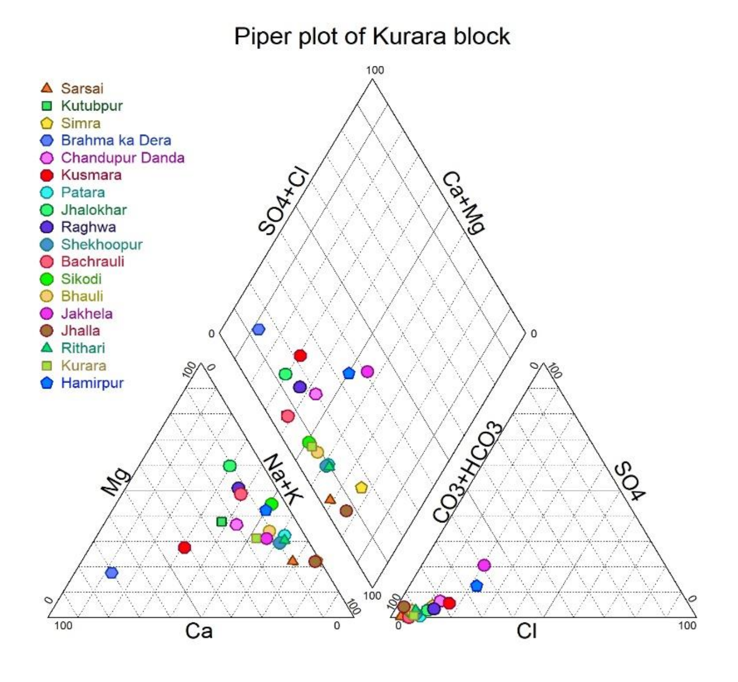

Figure (c): Piper plot of Kurara block

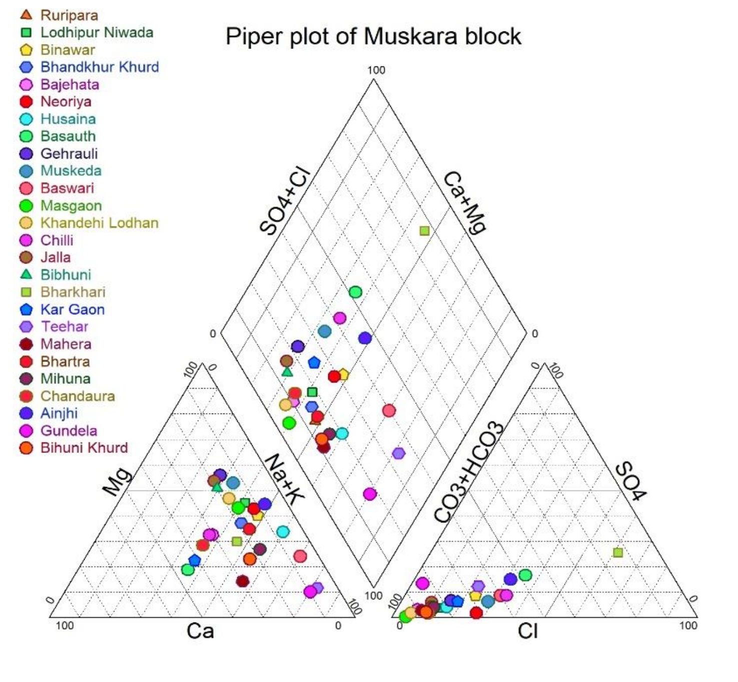

Figure (d): Piper plot of Muskara block

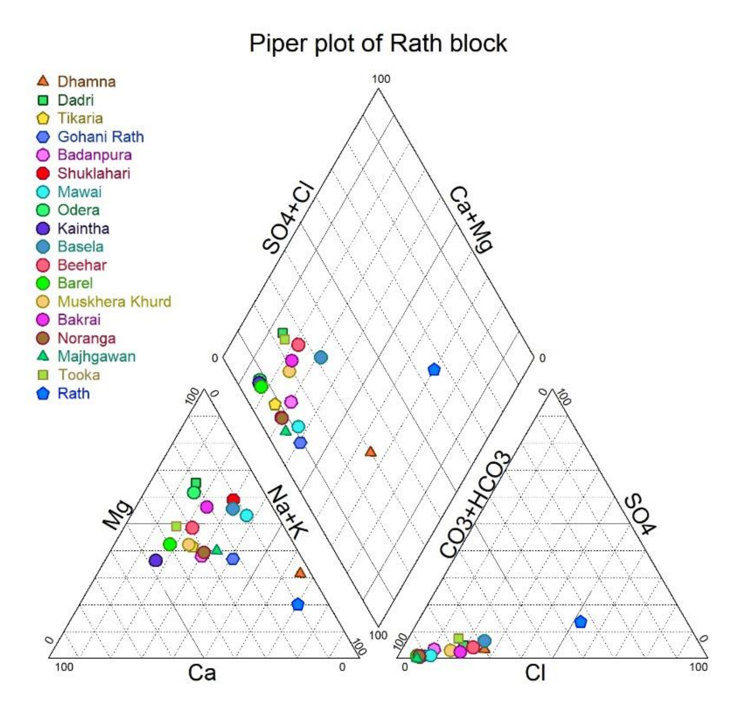

Figure (e): Piper plot of Rath block

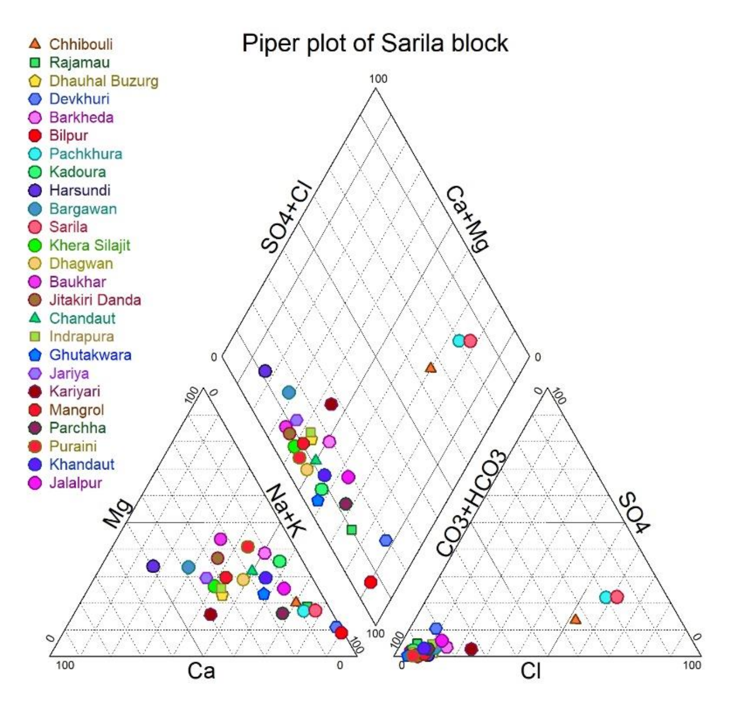

Figure (f): Piper plot of Sarila block

Figure 11(a) – 11(f): Trilinear Hill-Piper plots of unconfined aquifer

2.2.4 Classification with respect to agricultural use

As prescribed by IS 11624-1986 [17], the water quality of unconfined aquifer has been classified with respect to agricultural standards and classified below.

(i) <u>Total salt concentration</u> – It is expressed as Electrical Conductivity (EC) and in relation to the hazardous effect on soils, the classification is given below in Table 4 below.

Sl.No.	Class	Range of EC (µS/cm)	No. of samples
1.	Low	0 – 1,500	122
2.	Medium	1,500 – 3,000	25
3.	High	3,000 – 6,000	10
4.	Very High	> 6,000	3

Table 4: Summarized table of GW samples w.r.t EC

The majority of the samples (76.25% of total samples) lie in 'Low' class with reference to EC and are suitable for irrigation. Twenty-five samples (15.625% of total samples) lie in 'Medium' class and the soil requires some treatment prior to application of groundwater for irrigation. Ten samples (6.25% of total samples) lie in 'High' class and require extensive soil treatment and can be used under specific conditions. Only three samples, namely Khanna, Khandeh and Sayar of Maudaha block display very high EC values (>6,000 µS/cm) amounting to 1.875% of total samples lie in 'Very High' class and cannot be used for irrigation under any circumstance.

A spatial distribution map of EC values was prepared to demarcate areas with high EC values.

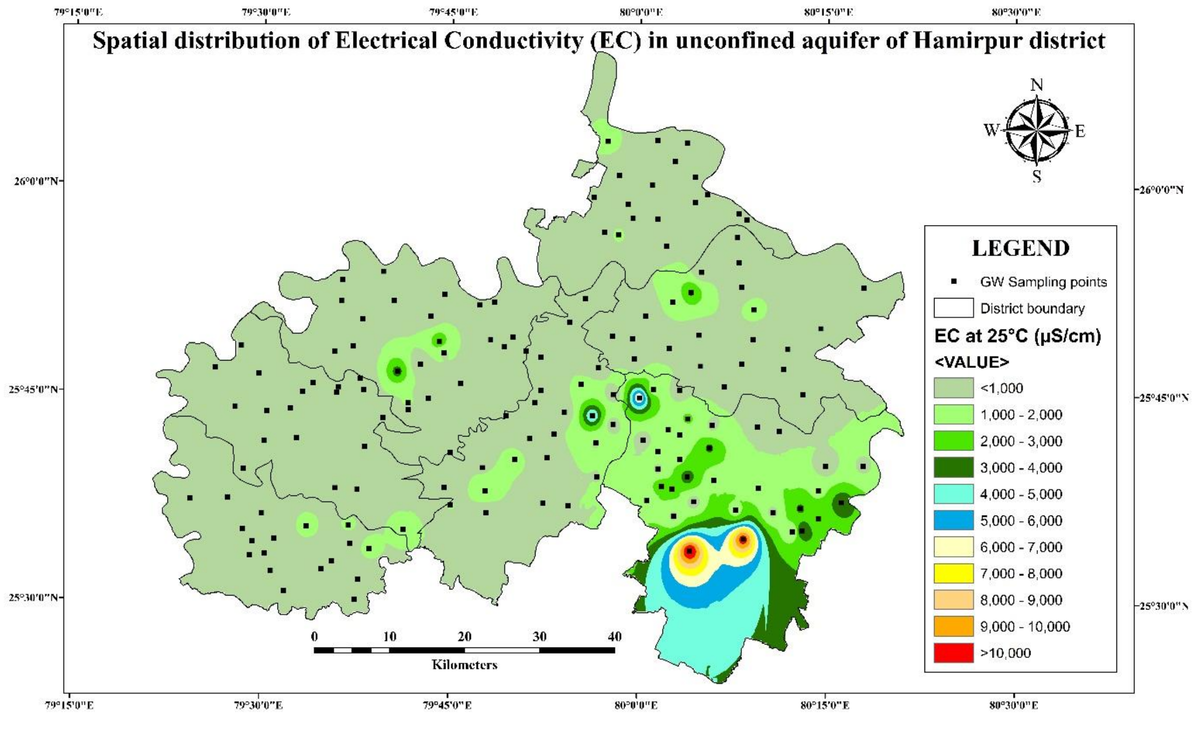

Figure 12: Spatial distribution map of Electrical Conductivity (EC) of unconfined aquifer

The spatial distribution map of EC indicates majority of the phreatic aquifer across the district is of good quality with EC<1,000µS/cm. Groundwater with EC between 2,000 to 5,000µS/cm is observed in all blocks whereas EC>7,000µS/cm is restricted to three sampling locations, namely Khanna, Khandeha and Sayar in Maudaha block. Other sampling locations nearby display anomalous EC values ranging from 1,000 to 3,000µS/cm closer to the aforesaid locations that bears a closer look into variation of EC.

(ii) Residual Sodium Carbonate – It is given with respect to hazardous effects of Bicarbonate ion concentration on soil and calculated by the following formula where all constituents are in meq/l:

$$RSC = (HCO_3^- + CO_3^{2-}) – (Ca^{2+} + Mg^{2+})$$

The classification as per standard is tabulated below in Table 5 below.

Sl.No.	Class	Range of RSC (meq/l)	No. of samples
1.	Low	< 1.5	68
2.	Medium	1.5 – 3.0	41
3.	High	3.0 – 6.0	28
4.	Very High	> 6.0	23

Table 5: Summarized table of GW samples w.r.t RSC

Sixty-eight samples (42.50% of total samples) lie in 'Low' class with reference to EC and are suitable for irrigation. Forty-one samples (25.625% of total samples) lie in 'Medium' class and the soil requires some treatment prior to application of groundwater for irrigation. Twenty-eight samples (17.50% of total samples) lie in 'High' class and can be used under exceptional circumstances. Twenty-three samples (14.375% of total samples) lie in 'Very High' class and are completely unfit for irrigation purposes.

(iii) Sodium Adsorption Ratio - It is an irrigation water quality parameter used in the management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water. It is also a standard diagnostic parameter for the sodicity hazard of a soil, as determined from analysis of pore water extracted from the soil.

It is calculated by the following formula:

$$SAR = \frac{Na}{\sqrt{Ca+Mg/2}}$$

The classification as per standard is tabulated below in Table 6 below.

Sl.No.	Class	Range of SAR (meq/l)	No. of samples
1.	Low	< 10	134
2.	Medium	10 - 18	17
3.	High	18 - 26	5
4.	Very High	> 26	4

Table 6: Summarized table of GW samples w.r.t SAR

Majority of the samples (83.75% of total samples) lie in 'Low' category with reference to SAR and there is negligible chance of soil salinity development. Seventeen samples (10.625% of total samples) lie in 'Medium' category and there is chance of development of soil salinity and precautions must be taken prior to application of groundwater for irrigation. Five samples (3.125% of total samples) lie in 'High' category and is unsuitable for irrigation except for exceptional circumstances. Four samples, namely Chahani Par, Kapsa, Khanna and Khandeh of Maudaha block amounting to 2.50% of total samples are unfit for irrigation except for highly salt tolerant crops.

2.2.5 Note on trace metals

(i) Total Chromium as Cr: No sample exceeds the acceptable limit of defined at 0.05 mg/l by BIS 10500:2012-2nd Revision (Amendment No.1 June 2015).
(ii) Copper: No sample exceeds the acceptable limit defined at 0.05 mg/l by BIS 10500:2012-2nd Revision (Amendment No.1 June 2015).
(iii) Iron: 37 samples exceed the acceptable limit defined at 0.3 mg/l by BIS 10500:2012-2nd Revision (Amendment No.1 June 2015) from a total of 54 samples.
(iv) Manganese: 2 samples exceed the permissible limit defined at 0.3 mg/l by BIS 10500:2012-2nd Revision (Amendment No.1 June 2015) from a total of 54 samples.
(v) Zinc: 1 sample exceeds the acceptable limit defined at 5 mg/l by BIS 10500:2012-2nd Revision (Amendment No.1 June 2015) from a total of 54 samples.
(vi) Total Arsenic as As: Samples collected lacked detectable Arsenic.

2.2.6 General Hydrochemistry of deeper aquifer

13 samples collected during exploration carried out in Hamirpur district between November 2012 to January 2013 to determine basic parameters. After chemical analysis, the samples were plotted on the trilinear Hill-Piper diagram [16] and the samples were classified into the following categories based on dominant cations and anions-

- 75% of samples lie on Mg^{2+}- HCO_3^- quadrant that indicate (Ca^{2+} + Mg^{2+}) > (Na^+ + K^+) and groundwater is shallow and fresh in nature,
- 8.33% of samples lie on Mixed type quadrant that indicate (Ca^{2+} + Mg^{2+}) + (CO_3^{2-} + HCO_3^-) > (Na^+ + K^+) + (Cl^- + SO_4^{2-}) and represents deep groundwater influenced by ion exchange,
- 8.33% of samples lie on Na^+ - HCO_3^- quadrant that indicate (Cl^- + SO_4^{2-}) > (CO_3^{2-} + HCO_3^-) and represents deep groundwater influenced by ion exchange,
- 8.33% of samples lie on Na^+ - Cl^- quadrant that indicate (CO_3^{2-} + HCO_3^-) > (Cl^- + SO_4^{2-}) and represents marine, deep and ancient groundwater.

GW quality data has been attached as Annexure -4.

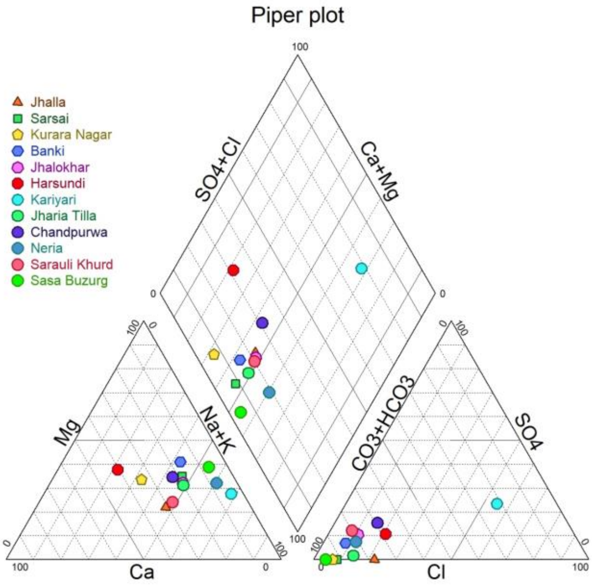

Figure 13: Trilinear Hill-Piper plot of deeper aquifer

2.2.7 Classification with respect to agricultural use

As prescribed by IS 11624-1986 [17], the water quality of unconfined aquifer has been classified with respect to agricultural standards and classified below.

(i) Total salt concentration – It is expressed as Electrical Conductivity (EC) and in relation to the hazardous effect on soils, the classification is given below in Table 7 below.

Sl.No.	Class	Range of EC (µS/cm)	No. of samples
1.	Low	0 – 1,500	11
2.	Medium	1,500 – 3,000	1
3.	High	3,000 – 6,000	-
4.	Very High	> 6,000	-

Table 7: Summarized table of GW samples w.r.t EC

The majority of the samples [91.66% of total samples] come under ‘Low’ class with reference to EC and are suitable for irrigation. Only one sample [8.33% of total samples] comes under ‘Medium’ class and the soil requires some treatment prior to application of groundwater for irrigation.

A spatial distribution map of EC values was prepared to demarcate areas with high EC values and has been attached as Figure 14 below.

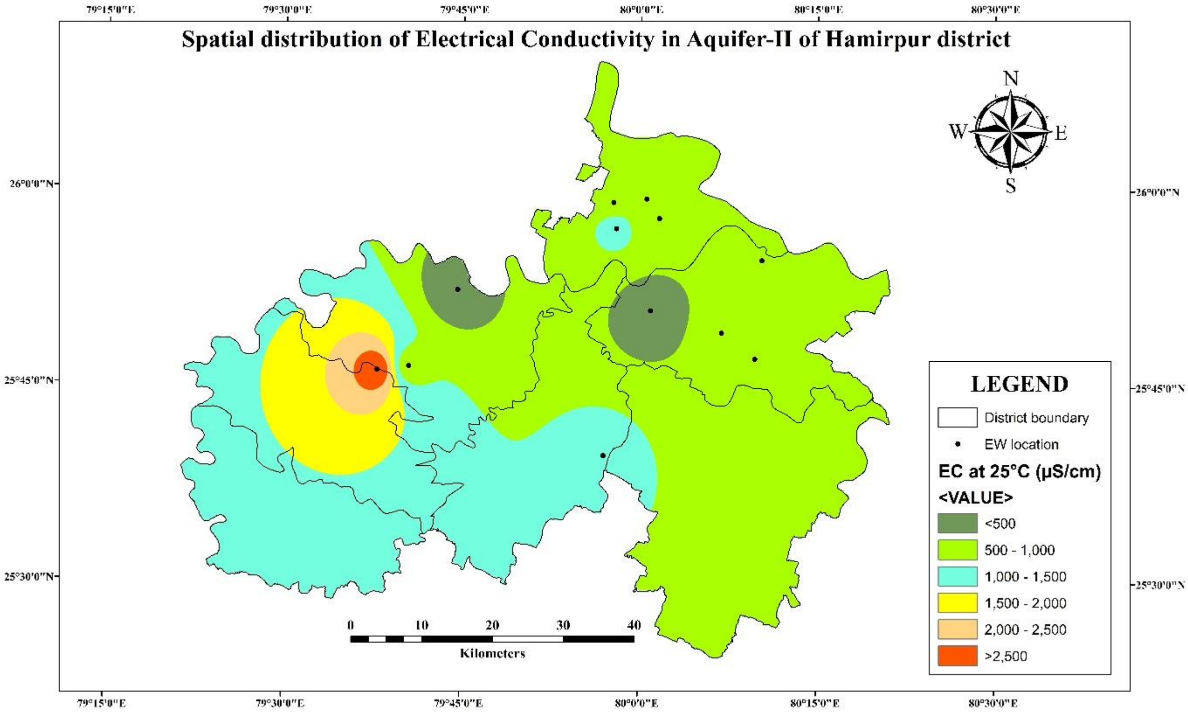

Figure 14: Spatial distribution map of Electrical Conductivity (EC) of deeper aquifer

Sampling locations with EC<500µS/cm is observed at two locations in Sumerpur and Sarila blocks whereas majority of Kurara, Sumerpur, Maudaha blocks in addition to parts of Muskara, Sarila, Gohand and Rath blocks display EC values between 1,000 to 1,500µS/cm. Only Kariyari in Gohand block displays EC value of 2,620µS/cm.

(ii) <u>Residual Sodium Carbonate</u> – It is given with respect to hazardous effects of Bicarbonate ion concentration on soil and calculated by the following formula where all constituents are in meq/l:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

The classification as per standard is tabulated below in Table 8 below.

Sl.No.	Class	Range of RSC (meq/l)	No. of samples
1.	Low	< 1.5	3
2.	Medium	1.5 – 3.0	5
3.	High	3.0 – 6.0	2
4.	Very High	> 6.0	2

Table 8: Summarized table of GW samples w.r.t RSC

Three samples [25% of total samples] come under ‘Low’ category with reference to RSC and are suitable for irrigation. Five samples [41.66% of total samples] come under ‘Medium’ class and the soil requires some treatment prior to application of groundwater for irrigation. Two samples [16.66% of total samples] come under ‘High’ class and can be used under exceptional circumstances. Two samples [16.66% of total samples] come under ‘Very High’ category and are completely unfit for irrigation purposes.

(iii) Sodium Adsorption Ratio - It is an irrigation water quality parameter used in the management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water. It is also a standard diagnostic parameter for the sodicity hazard of a soil, as determined from analysis of pore water extracted from the soil.

It is calculated by the following formula:

$$SAR = \frac{Na}{\sqrt{Ca+Mg/2}}$$

The classification as per standard is tabulated below in Table 9 below.

Sl.No.	Class	Range of SAR (meq/l)	No. of samples
1.	Low	< 10	11
2.	Medium	10 - 18	1
3.	High	18 - 26	-
4.	Very High	> 26	-

Table 9: Summarized table of GW samples w.r.t SAR

Majority of the samples [91.66% of total samples] come under ‘Low’ category with reference to SAR and there is negligible chance of soil salinity development. Only one sample [8.33% of total samples] comes under ‘Medium’ category and there is chance of development of soil salinity and precautions must be taken prior to application of groundwater for irrigation.

2.2.8 Note on trace metals

No data available.

2.2.9 For Industrial purposes –

Nearly each manufactured product uses water during some part of the production process. Industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility. Some industries that use large amounts of water produce such commodities as food, paper, chemicals, refined petroleum, or primary metals.

(i) Langelier Saturation Index : Langelier [18] proposed a formula to calculate Calcium carbonate scaling in water based on pH, TDS, temperature and total alkalinity based on the following formula –

$$LSI = pH – pH_s$$

wherein,

pH is the actual pH of water and

pH_s is the pH at saturation and calculated by :

- A = [log10(TDS)-1]/10
- B = -13.12*log10(°C+273) + 34.55
- C = log10*[Ca^{2+} as $CaCO_3$] – 0.4 and
- D = log10*[Alkalinity as $CaCO_3$] – 0.4

LSI > 0 indicates water is super-saturated w.r.t $CaCO_3$ and $CaCO_3$ layer precipitates,

LSI = 0 indicates water is in equilibrium and $CaCO_3$ precipitates nor causes corrosion,

LSI < 0 indicates water is undersaturated w.r.t $CaCO_3$ and dissolves it causing corrosion.

Carrier [19] further classified the values and his modification is described below –

LSI = -2.0 to <-0.5: water has potential to cause serious corrosion,

LSI = -0.5 to <0: water is slightly corrosive and no scale formation is seen,

LSI = 0: water is in equilibrium w.r.t $CaCO_3$ but pitting corrosion possible,

LSI = >0 to 0.5: water is slightly corrosive and slight scale formation is possible,

LSI = >0.5 to 2: water is non-corrosive and scale formation is likely.

(ii) Ryznar Stability Index: Ryznar [20] also proposed a formula to predict Calcium carbonate scaling in groundwater and overcame deficiencies in LSI. It is calculated by –

$$RSI = 2\ pH_s – pH$$

wherein,

pH is the actual pH of water and

pH_s is the pH at saturation in $CaCO_3$.

RSI < 6: increasing tendency for scale formation with decreasing index,

RSI = 6 – 7: non-corrosive protective film formed by $CaCO_3$ in water,

RSI > 8: tendency of water for corrosion.

(iii) Puckorius Scaling Index : Puckorius and Brooke [21] proposed a formula to calculate $CaCO_3$ formation based on buffering capacity of water & maximum quantity of precipitate that can form in bringing water to equilibrium. Water rich in Ca^{2+} but with lower alkalinity and buffering capacity can have higher $CaCO_3$ saturation level. High Ca^{2+} level increases ion activity product and such waters may have high tendency to form scales due to driving process but scales formed are of low to negligible quantity. Water has driving force but lacks capacity and ability to maintain pH as precipitate matter forms. It is calculated by –

$$PSI = 2\ pH_s - pH_{eq}$$

wherein,

pH_s is the pH at saturation in $CaCO_3$,

pH = 1.465*log10[Alkalinity] + 4.54

PSI < 6 indicates water is corrosive and dissolves $CaCO_3$ scale,

PSI > 6 indicates water is scale forming in nature.

(iv) Larson-Skold Index: Larson and Skold [22] gave a formula to predict the corrosivity of water towards mild steel and is calculated by –

$$LR = Cl + SO_4 / CO_3 + HCO_3$$

All ionic concentrations in meq/l

LR < 0.8: Chlorides and Sulphates may not interfere with scale formation,

LR = 0.8 – 1.2: Chlorides and Suplhates may interfere with natural film formation and higher than desired corrosion rates expected,

LR > 1.2: very high corrosion rate expected.

(v) Potential to Promote Galvanic Corrosion: Also called Chloride Sulphate Mass Ratio [23] and is an indicator of corrosion of galvanic items by water. It is calculated by –

$$PPGC = Cl / SO_4$$

Values in mg/l

CSMR > 0.5: indicates corrosion of galvanic items.

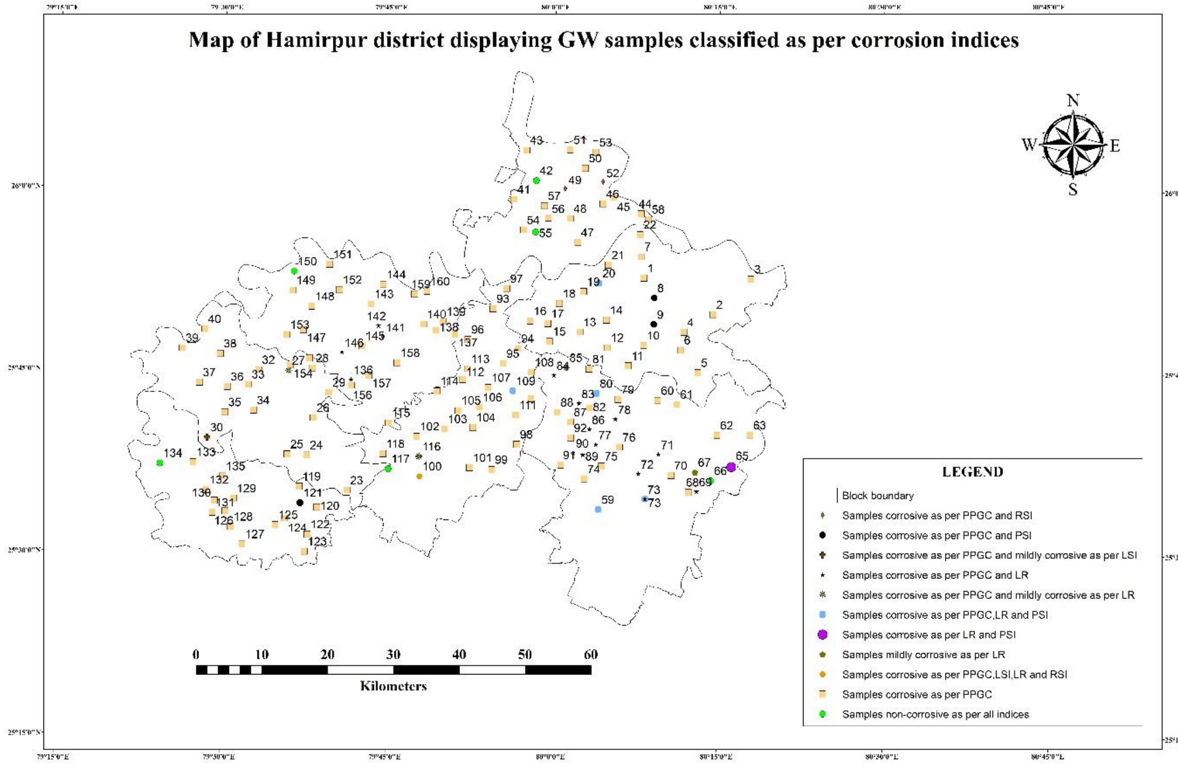

Figure 15: Map displaying Groundwater of unconfined aquifer classified as per corrosion indices

Majority of the groundwater samples collected from phreatic aquifer display corrosion tendency as per PPGC (Potential to Promote Galvanic Corrosion) and is an indication that the groundwater structures planned there must not possess Lead (Pb) as solder as it is liable to enter groundwater. Sumerpur block is the industrial hub of Hamirpur district and groundwater there indicates corrosion as per PPGC, LR (Larson-Skold Index) and PSI (Puckorius Scaling Index).

- **Groundwater quality comparison between unconfined and deeper aquifer**

The difference in quality with respect to different ions/elements present in unconfined and deeper aquifer has been tabulated below in Table 10.

Constituents	Limits as per BIS 10500-2012: 2nd Revision	Aquifer – I			Aquifer – II		
		Min	Max	No. of Samples above MPL	Min	Max	No. of Samples above MPL
pH	6.5 – 8.5	6.72	8.94	11	7.30	8.45	-
EC (µS/cm)	No limits	403	12,200	-	450	2,620	-
TDS	500 – 2,000 mg/l	249.86	7,332	13	-	-	-
Calcium	75 -200 mg/l	2.00	476.95	4	10.00	84.00	-
Magnesium	30 – 100 mg/l	6.02	294.06	8	15.00	102.00	1
Potassium	No limits	0.48	141.60	-	0.00	2.50	-
Sodium	No limits	8.74	1,925.00	-	29	478	-
Carbonate	No limits	0.00	138.00	-	0.00	30.00	-
Bicarbonate	No limits	140.30	1,091.90	-	244.00	780.00	-
Chloride	250 – 1,000 mg/l	10.14	3,580.45	3	16.00	596.00	-
Sulphate	200 – 400 mg/l	0.00	1,780.00	11	0.00	343.00	-
Nitrate	45 mg/l (acceptable)	0.00	699.00	14	0.00	11.00	-
Fluoride	1.00 mg/l (acceptable); 1.50 mg/l (permissible)	0.22	3.26	26	0.00	1.60	1
Arsenic	0.01 mg/l (acceptable)	-	-	-	-	-	No data available
Chromium	0.05 mg/l (acceptable)	0.011	0.02	-	-	-	No data available
Iron	1.0 mg/l (acceptable); 1.5 mg/l (permissible)	0.005	8.45	11	-	-	No data available
Manganese	0.1 mg/l (acceptable); 0.3 mg/l (permissible)	0.002	0.50	2	-	-	No data available
Copper	0.05 mg/l (acceptable); 1.5 mg/l (permissible)	0.002	0.50	-	-	-	No data available
Zinc	5 mg/l (acceptable); 15 mg/l (permissible)	0.02	9.48	-	-	-	No data available

Table 10: Comparison of GW quality

2.3 Aquifer disposition

To understand the spatial and hydrogeological characteristics of aquifers, exploratory drilling coupled with electrical logs and pumping tests were utilized for detailed understanding of underlying aquifers.

2-D and 3-D Aquifer Disposition of Hamirpur district

The available drilling history/lithologs coupled with electrical logs were utilized to create 2-D and 3-D stratigraphic models, fence and panel diagrams of the district for visualization of lithologies and different aquifer groups present in the district. The fence diagram of the district has been attached below as Figure 16, along with the names of the exploratory boreholes and slim holes.

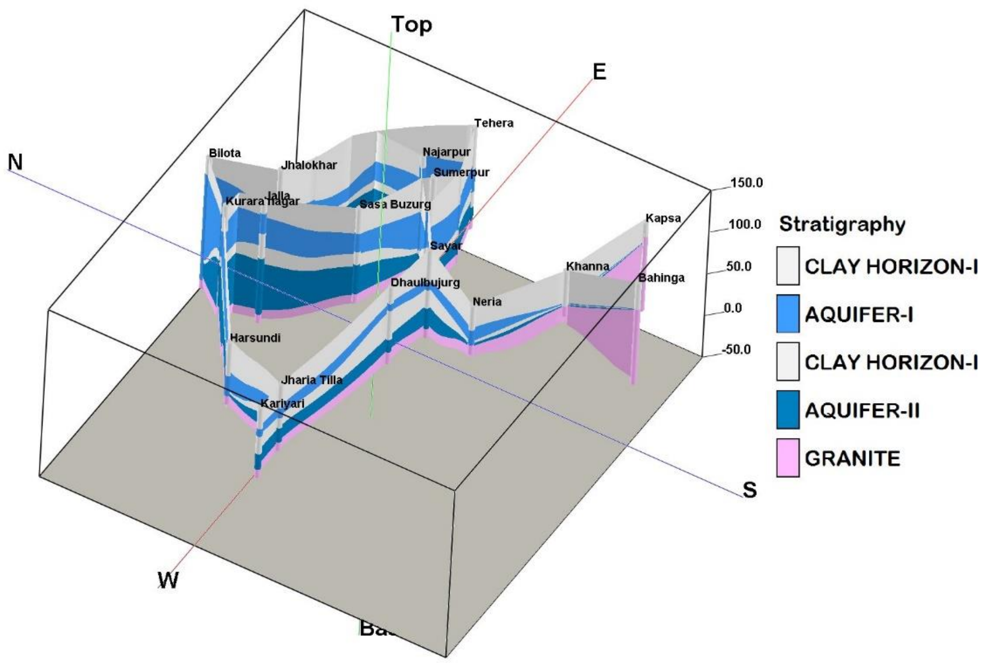

Figure 16: Fence diagram of Hamirpur district

As visualized from the fence diagram, it is evident that the extent of clay horizons in addition to thickness of aquifers decrease from North to South direction and the same trend is observed in West to East direction. The Granitic basement underlain by the Quaternary alluvium. The Quaternary alluvium is represented by cyclic succession of sand, silt and clay.

Thickness of Quaternary alluvium increases from 25 mbgl at Tinduhi in Maudha block to 140 mbgl at Sarsai in Kurara block. Alluvial thickness in the southern portion of the district is considerably less as Granitic basement is encountered within shallow depths and the trend of increasing alluvium to the north is due to the deposition of 2 major rivers, Yamuna and Betwa. Near constant thickness of alluvium is observed from Kariyari in Gohand block at 73 mbgl (western portion of the district) to 76 mbgl at Tehera in Sumerpur block (eastern portion).

KURARA BLOCK

The exploratory borehole data of 6 locations – Bilota, Sarsai, Kurara Nagar, Jhalla, Kanota Tanda and Surajpur have been incorporated into a 3-D stratigraphic model and displayed below as Figure 17.

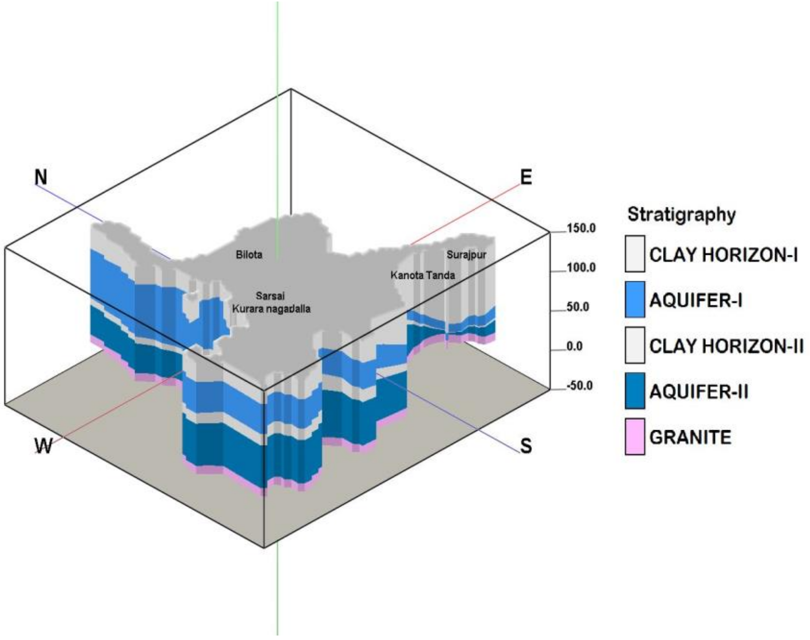

Figure 17: 3-D stratigraphic model of Kurara block

The fence diagram of the same has been attached as Figure 18 below. The surficial clay layer starts to diminish from South-east towards the North-eastern direction. The reverse is applicable for the extent of Aquifer – 1 that increases towards the North-east. A thin clay layer separates the two aquifer layers from each other. The thickness of Aquifer – 2 is seen in the form of a lens between Surajpur and Jhalla exploratory wells with the aquifer reaching it's zenith between Jhalokhar and Kanota Tanda. The extent of Aquifer – 2 towards the west and pinches out towards north. Aquifer – 2 is underlain by Bundelkhand Granite. Aquifer -1 extends from ground surface down to the average depth of 30 mbgl. Aquifer – 2 is found between the depth ranges of 51 mbgl to 117 mbgl.

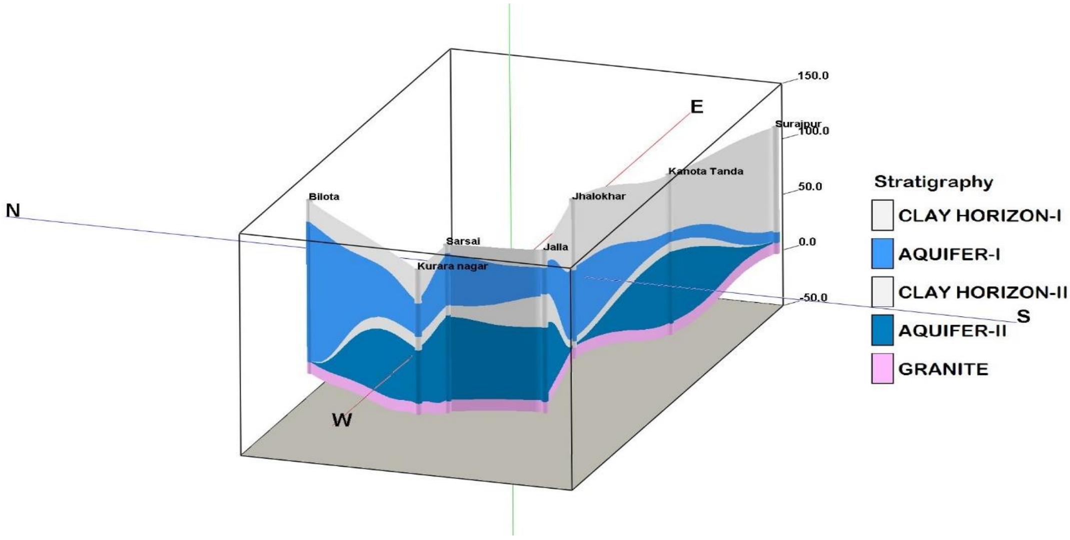

Figure 18: Fence diagram of Kurara block

MAUDAHA BLOCK

The fence diagram of Maudaha block has been attached below as Figure 19. The surficial clay layer displays nearly the same thickness between Ghusiari and Bahinga, increasing towards Khanna and then decreasing towards Neria and has thickness towards Sayar. Aquifer – 1 is observed as a very thin patch between Ghusiari and Khanna. Two aquifer groups are separated by a clay layer between Neria and Sayar, towards the north-west. Exploratory drilling at Bahinga, Ghusiari and Khanna reveals Aquifer – 1 extends from ground surface down to 37 mbgl. Granitic basement was encountered prior to 50 mbgl. Exploratory drilling at Neria and Sayar reveals Aquifer – 2 between 68 mbgl to 89 mbgl.

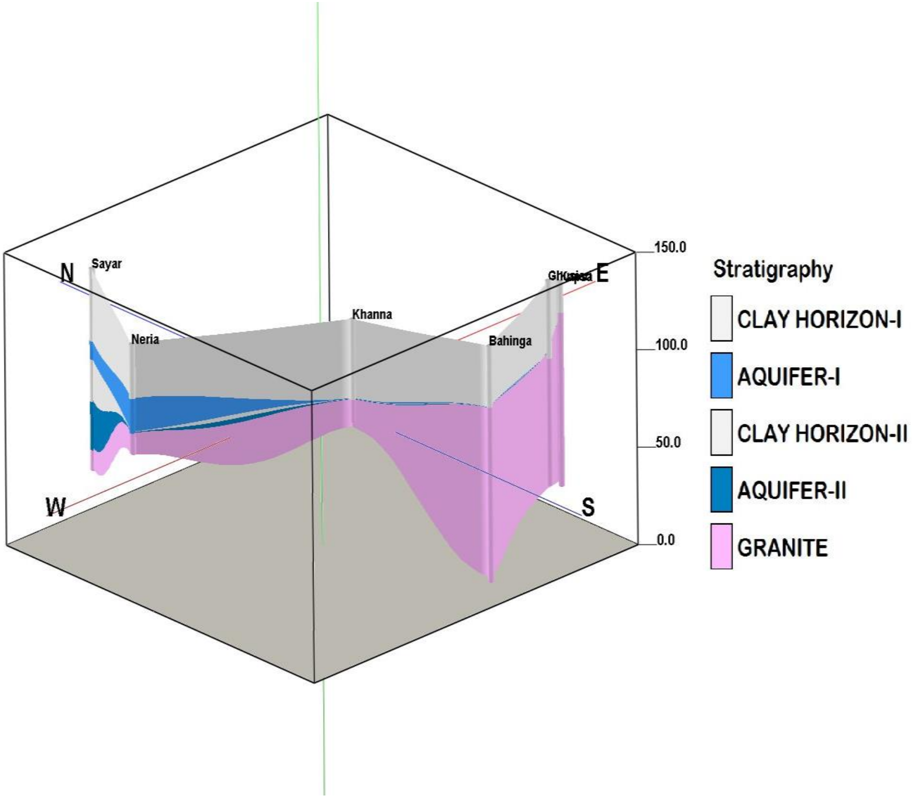

Figure 19: Fence diagram of Maudaha block

SARILA BLOCK

The fence diagram of Sarila block has been attached below as Figure 20.The thickness of surficial clay increases from South-west at Kariyari towards North-east at Harsundi and the same trend is observed in areal extent of Aquifer – 1. Second clay layer starts to decrease from Kariyari towards Jharia Tilla and is almost absent towards Harsundi. Exploratory drilling at Harsundi, Jharia Tilla and Kariyari reveals Aquifer – 1 extends from ground surface down to 31 mbgl and Aquifer – 2 is present between 47 mbgl to 68 mbgl. Aquifer – 2 is underlain by Granitic basement.

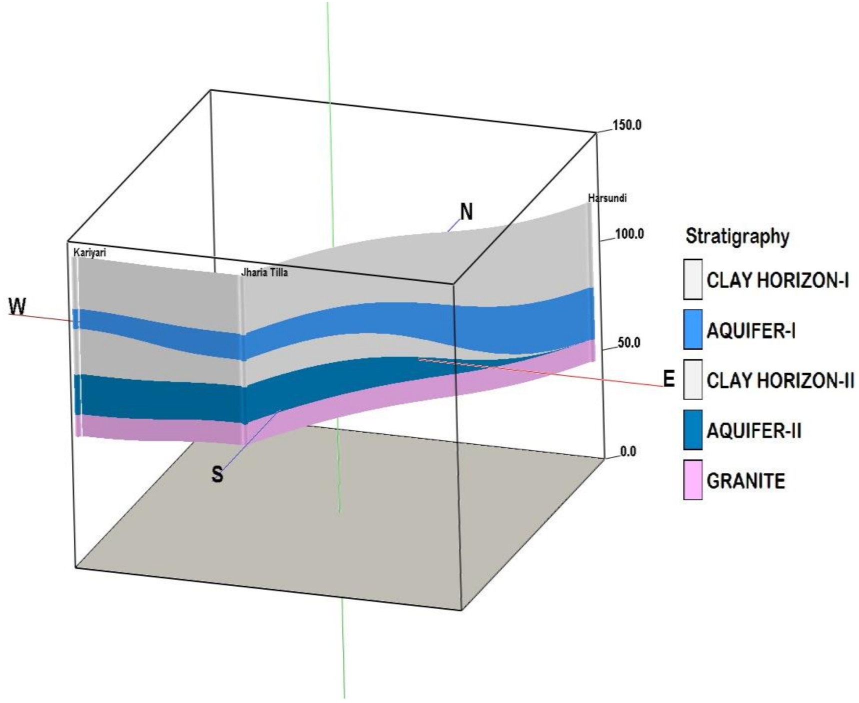

Figure 20: Fence diagram of Sarila block

SUMERPUR BLOCK

The 3-D stratigraphic model of Sarila block has been attached below as Figure 21.The thickness of Clay layer – 1 decreases from west to east and the same is observed in the north to south direction. The reverse case is true for the areal extent of Aquifer – 1. Aquifer – 1 extends from ground surface down to 35 mbgl and Aquifer – 2 is found between the depths of 41 mbgl to 87 mbgl. The thickness of Clay layer – 2 separating the Aquifer – 2 from Aquifer – 1 appears to be of uniform thickness throughout the block. Aquifer – 2 is underlain by Granitic basement.

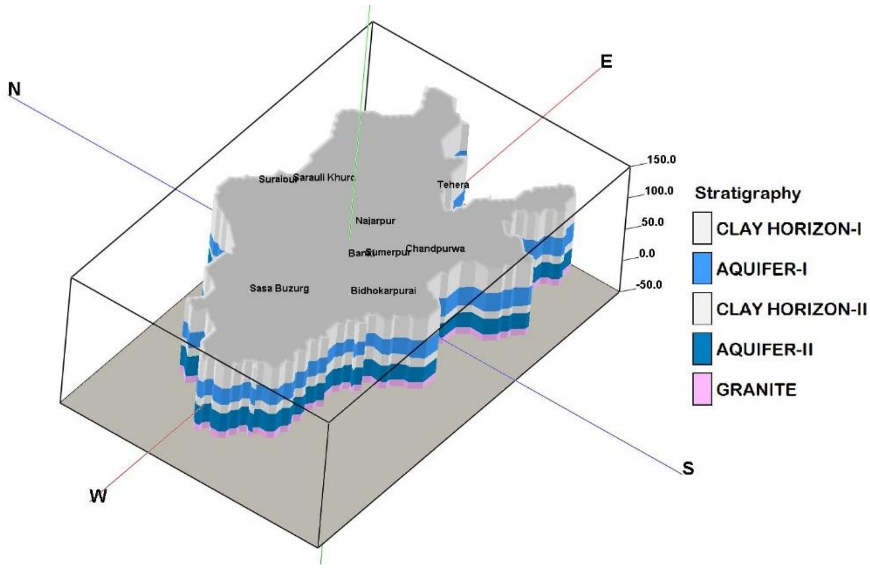

Figure 21: 3-D stratigraphic model of Sarila block

2.4 Aquifer characteristics

Based on available data, two aquifer groups were demarcated in the district. The first aquifer group occurs in unconfined condition and lithology includes fine to medium grained sand. The second aquifer group occurs under semi-confined to confined condition and lithology encountered was mainly medium to coarse grained sand. The aquifer parameters were determined on the basis of pumping tests in successful wells and are given below -

- Transmissivity = 854.78 m^2/day to 4,107 m^2/day
- Storativity = $1.25*10^{-3}$ to $7.59*10^{-5}$
- Hydraulic Conductivity = 48.44 m/day to 92.55 m/day

3. GROUNDWATER RESOURCE POTENTIAL

The groundwater resource assessment for the study area was carried out as per GEC-2015 and has been summarized below in Table 12. As per Table 11, the study area comprising a geographic sum total of 3,81,540 Ha area has groundwater recharge worthy area wholly under non-command area with the predominant geological formation being alluvium.

Sl. No.	Block	Predominant Geological Formation	Total Geographical area (Ha)	Hilly area (Ha)	GW recharge worthy area(s)		
					Command area (Ha)	Non-Command area (Ha)	Poor GW quality area
1	Gohand	Alluvium	50714	0	0	50714	0
2	Kurara	Alluvium	43214	0	0	43214	0
3	Maudaha	Alluvium	65136	0	0	65136	0
4	Muskara	Alluvium	51398	0	0	51398	0
5	Rath	Alluvium	45013	0	0	45013	0
6	Sarila	Alluvium	67068	0	0	67068	0
7	Sumerpur	Alluvium	58997	0	0	58997	0
	TOTAL		**381540**	**0**	**0**	**381540**	**0**

Table 11: Groundwater recharge worthy area of Hamirpur district in Ha

Sl. No	Block	Annual Extractable Groundwater Recharge (Ham)	Current Annual Ground Water Extraction for Irrigation (Ham)	Current Annual Ground Water Extraction for Domestic And Industrial Use (Ham)	Current Annual Ground Water Extraction for all uses (Ham)	Annual GW Allocation for Domestic use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Development (%)	Category
1	Gohand	4049.76	2691.60	241.83	2933.43	241.83	1116.34	72.43	SEMI-CRITICAL
2	Kurara	6241.64	3931.35	287.86	4219.21	405.16	1905.13	67.60	SAFE
3	Maudaha	4642.50	3201.80	522.59	3724.39	750.17	690.53	80.22	SEMI-CRITICAL
4	Muskara	7816.44	3547.60	319.96	3867.56	399.31	3869.53	49.48	SAFE
5.	Rath	7227.56	5254.08	354.33	5608.41	371.69	1601.79	77.60	SEMI-CRITICAL
6.	Sarila	5523.24	4085.04	268.82	4353.86	306.52	1131.68	78.83	SEMI-CRITICAL
7.	Sumerpur	7443.08	5657.60	576.16	6233.76	582.26	1203.22	83.75	SEMI-CRITICAL
	Total	**42944.22**	**28369.07**	**2571.54**	**30940.61**	**3056.95**	**11518.21**	**72.05**	**N.A.**

Table 12: Groundwater Resource Assessment (as per GEC-2015)

Map displaying the Net Annual groundwater availability in addition to Existing Gross groundwater for all uses (Ham) and Stage of groundwater development (%) across all blocks of Hamirpur district has been attached below as Figure 22.

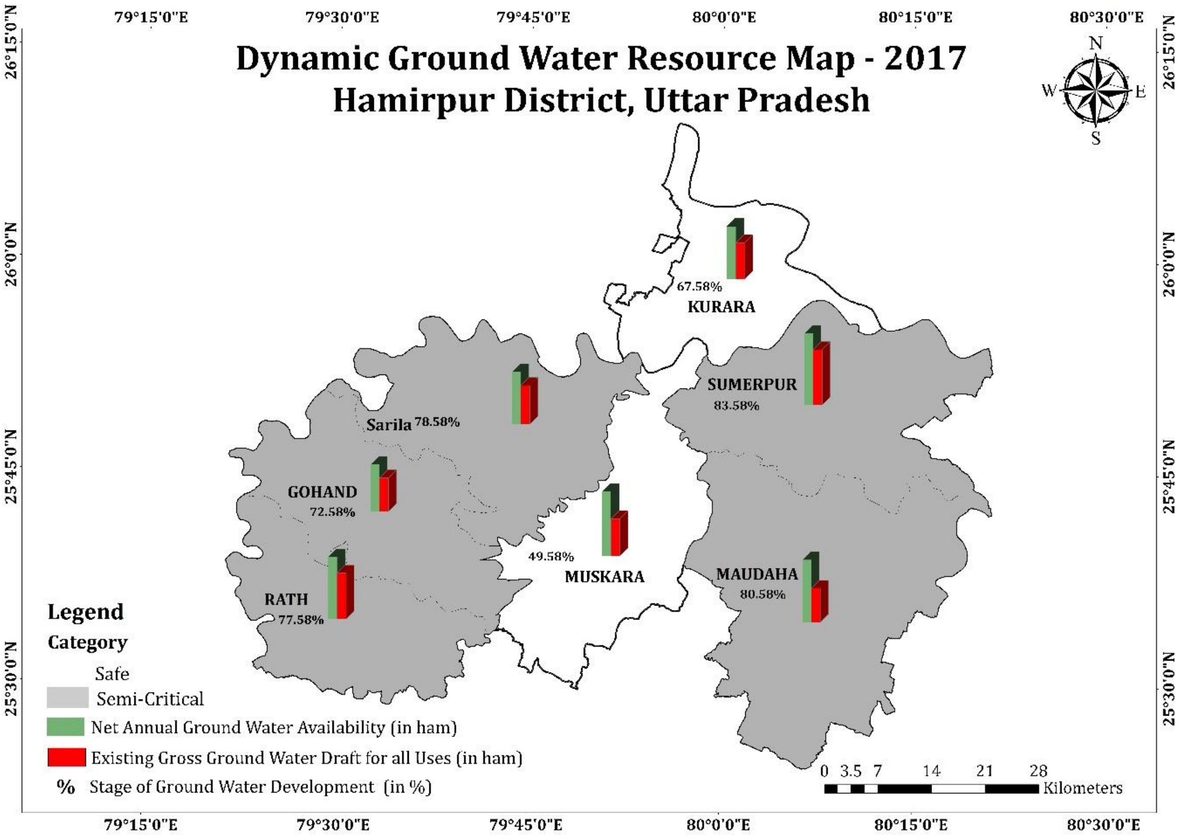

Figure 22: GW Resource Map of Hamirpur district

4. GROUNDWATER RELATED ISSUES

4.1 Identification of issues

(i) The thickness of aquifer occurring in the form of varied granularity of sand extends from 6m in the southern portion of the district to 44m in the north. The thickness of aquifer is directly proportional to the availability of groundwater (.i.e. quantity). Thickness of alluvium in the study area is meagre compared to the thickness of alluvium found in the Gangetic basin.

(ii) Increasing share of groundwater for irrigation: The contribution of groundwater for irrigation in the district has taken precedence over surface water irrigation from canals due to subsidies availed by cultivators, ease in procuring pumpsets and advancement in technology leading to over-exploitation of groundwater [24]. The data has been represented in the form of charts and has been attached below as Figures 23 and 24 respectively. Data has been attached as Annexure -5.

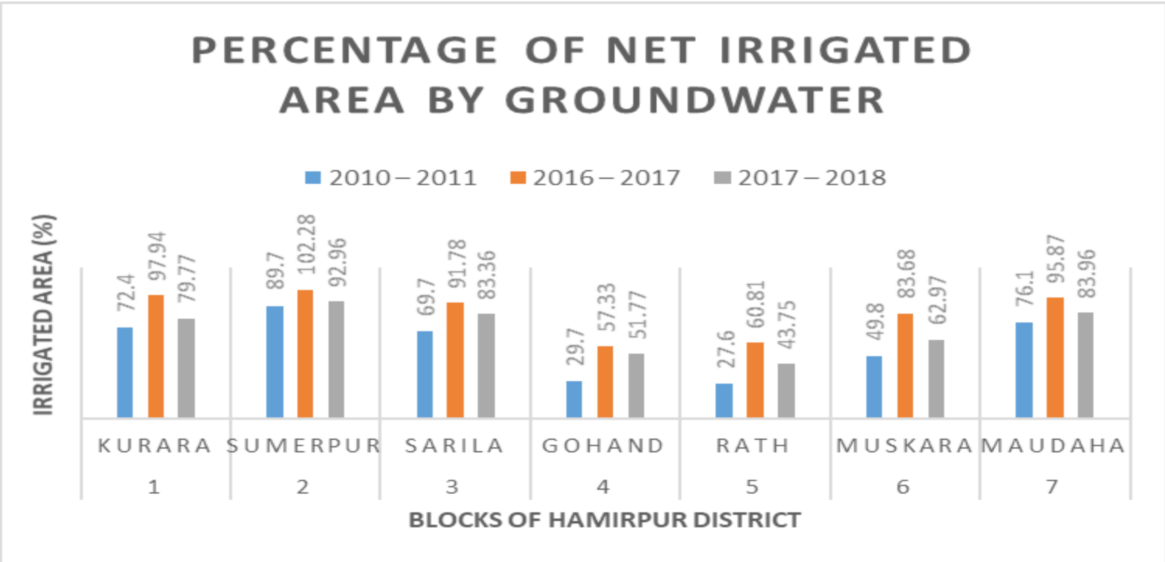

Figure 23: Comparison of contribution of groundwater irrigation sources over time

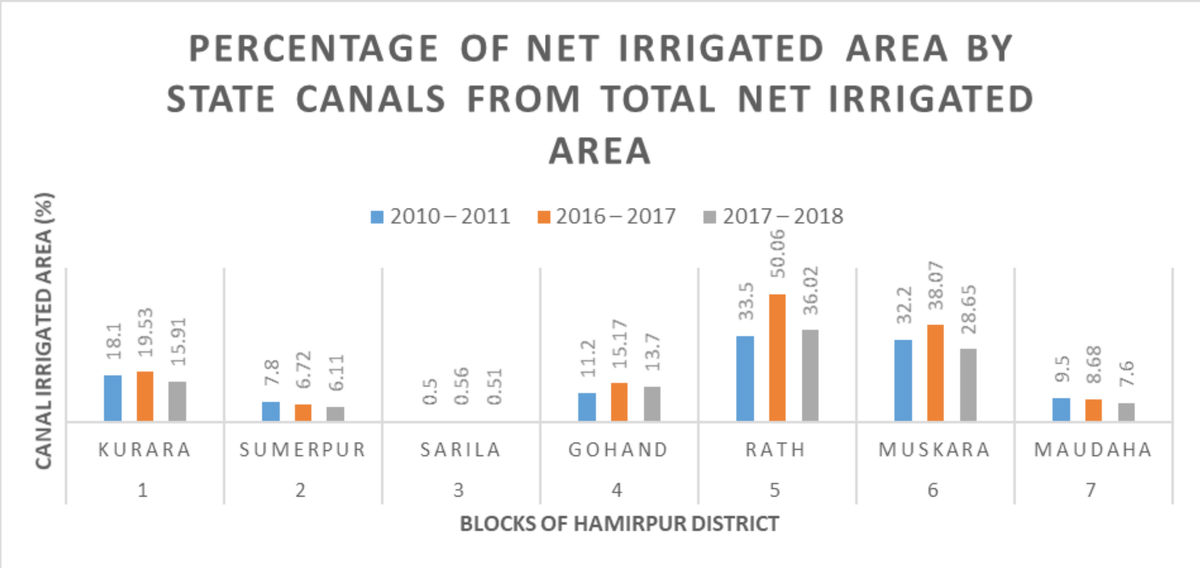

Figure 24: Contribution of canals towards irrigation

(iii) Due to erratic rainfall coupled with frequent bouts of drought, the semi-arid climate poses the biggest challenge as some amount of rainfall evaporates prior to reaching ground surface. Perusal of the rainfall data of last 50 years displays declining trend and will result in lesser rainfall recharging underlying aquifers.

(iv) Geological setup: Granitic basement is encountered at shallow depth in the southern portion of the district (<50 mbgl) when compared to the northern portion of the district (>125 mbgl). Coupled with thickness of surficial clay, this poses a challenge for percolation of rainfall.

(v) Geomorphological setup: The northern and central portions of the district are characterized by the depositional environments of two major river systems – Yamuna and Betwa. Virma river flowing from South-west to North-East has resulted in ravinous topography rendering the land inhospitable for agriculture.

4.2 Groundwater quality issues and contamination:

(i) High TDS in unconfined aquifer is a major matter of concern as 54.34% of samples have TDS between 500 – 2,000 mg/l and 8.125% of samples have TDS > 2,000 mg/l.

(ii) Nitrate in unconfined aquifer occurs in isolated patches and is majorly from anthropogenic inputs.

(iii) Fluoride in unconfined aquifer is another matter of concern as 36.25% of samples have Fluoride content between 1.0 – 1.5 mg/l and 16.25% of samples have > 1.5 mg/l of Fluoride.

5. GROUNDWATER MANAGEMENT STRATEGIES

Management strategies have to be adopted and implemented by the concerned agencies in a timely fashion to prevent the increasing pressure on groundwater resources and to increase the availability of the aforesaid resource. Management strategies have been divided into Demand and Supply side interventions for implementation and tabulated below.

SUPPLY SIDE INTERVENTIONS	DEMAND SIDE INTERVENTIONS
1. Construction and maintenance of Managed Aquifer Recharge structures viz. Dams/ponds/percolation tanks/gabion structures etc.	1. Promotion of drip and sprinkler/pressurized irrigation to enhance irrigation efficiency as opposed to traditional flood irrigation method.
2. Carrying out de-siltation of streams, ponds, tanks and surface water catchments to increase storage.	2. Development of new variety of pulses with high per hectare yield and promoting cultivation of pulses with incentives.
3. Large scale afforestation measures to capture soil moisture by transplantation of local species.	3. Diversification of cropping pattern to promote cultivation of oil seeds.
4. Increasing greenery in ravines for carbon sequestration and combating climate change	4. Development of new variety of wheat that requires less input of water.
5. Construction of Rainwater harvesting structures at suitable locations.	5. Measures to decrease evapo-transpiration losses.

Table 13: Proposed Supply side and Demand side interventions

5.1 Supply Side Interventions

It has been proposed to adopt such measures only in groundwater stressed blocks in order to increase the quantum of available water by increasing storage, promoting community participation in revival and restoration of traditional water bodies like tanks, ponds etc. and suitable rainwater harvesting structures at urban places. The different interventions have been described below –

1. Construction and maintenance of Managed Aquifer Recharge structures

It has been proposed to adopt such measures in order to increase the quantum of available water by increasing storage, ensuring water supply isn't affected during drought periods. The different interventions have been described below –

(i) Construction of check dams, gabions and farm ponds to the tune of 280 Nos. will result in increasing irrigation potential to the tune of 3.97 MCM.

(ii) Studies at micro-watershed level to collect and analyze hydrological data that be helpful in preparation of village level management plans with the help of community participation.

2. Carrying out de-siltation of streams, ponds, tanks and surface water catchments to increase storage.

(i) Desilting of traditional water bodies like tanks, ponds etc. will result in increased storage area by capturing surplus rainfall and can be utilized for domestic and irrigation purposes.
(ii) In addition to increasing storage area, the measures will also help in slowing down the rate of gully/ravine formation as rainfall will be confined to one place instead of eroding top-soil and sub-soil with greater velocity during extreme rainfall events.

3. Large scale afforestation measures to capture soil moisture by transplantation of local species

(i) Giving moderate slope (<6%) to vertical banks of gully head and plantation of strips with perennial tall grass like *Saccharum munja* (Munja grass) and bushes such as *Ziziphus nummularia* (Jhar beri), *Crotalaria burhia* (Burhia rattlepod), Balanites roxburghii (Hingot), Carissa carandas (Karonda) etc.
(ii) Slopping land (3–6% slope) with shallow/medium soil: Agronomical measures, i.e., strip/contour planting against slope (grass strips between crop strips for assuring low soil losses) with following crops: Green gram, Pearl millet and Pigeon pea-cluster bean intercropping.
(iii) Mild slope land (>1–3% slope) with medium/deep soil: Green gram-taramira (*Eruca sativa*) and Pearl millet-mustard cropping systems.
(iv) Flat land (1% or fewer slopes) with deep soil: suitable for intensive cropping system, i.e., Sesame-taramira, Pearl millet-mustard and Green gram-wheat [1].

4. Reclamation of ravines by the following interventions

(i) Pin-pointing of main gully and construction of composite Gabions (lower part composed of masonry and upper portion of dressed boulder) will help in collection of silt and other debris rich in organic matter during monsoon. Regular maintenance is of utmost importance.

Figure 25: Composite gabion structure to check ravine formation

(ii) Masonry structures: The site selected for construction must be at an elevated portion compared to steep channel slope of ravine. A foundation of 45 – 60 cm beneath flow line is recommended. In silt retention type check dams, provision of 1 or 2 holes (5 – 7 cm in diameter) at 0.30 – 0.60 m below crest level should be made for disposing surplus runoff and and the stones should form a gradual slope to the downstream side of the dam.

Figure 26: Masonry structure to check ravine formation

(i) Earthen check dams: Can be constructed in gullies to check bed corrosion by stabilization through silt deposition during monsoon. Rainfall is impounded behind the dam for 2 -5 months after monsoon depending on dimensions. If bed of gully is pervious in nature, it will recharge groundwater level **[25]**.

5. Increasing greenery in ravines for carbon sequestration and combating climate change

Replication of 5 modules designed for ravine reclamation in Morena district of Madhya Pradesh state under NICRA project titled 'Niche Area of Excellence on management of soil health and productivity in ravinous land.' Each module included a mix of forest and fruit trees, crops and medicinal plants. Each module can be tested at locations as a part of pilot project and the successful ones can be adapted for widespread use according to agro-climatic conditions. The modules have been described below –

- M1 (diversified cropping system module): The cropping pattern included Pearl Millet - Mustard, Pearl millet-Taramira (*Eruca sativa*), Green gram/Black gram-Mustard, Sesbania (*Sesbania acuminata*) - Mustard, Soybean-Mustard, and Pigeon pea + Cluster bean intercropping.
- M2 (agri-horti module): Intercrops grown with fruit trees included Aonla (*Emblica officinalis*) + Pearl millet – Sesamum; Custard apple (*Annona reticulata*) + Sesbania – Mustard – Maize fodder; Guava (*Psidium guajava*) + Green gram – Taramira; Ber (*Ziziphus mauritiana*) + Pigeon pea; Drumstick (*Moringa oleifera*) + Zinger (*Zingiber officinale*) – Taramira; and Pomegranate (*Punica granatum*) + Castor – Chickpea.
- M3 (horti-medicinal/pastoral module): Guava (*Psidium guajava*) + Anjan grass (*Cenchrus ciliaris*); Ber (*Ziziphus mauritiana*) + Stylo (*Stylosanthes scabra*); Aonla (*Emblica officinalis*) + Guria grass (*Chrysopogon fulvus*); Ber (*Ziziphus mauritiana*) + Spanish grass (*Cymbopogon aciculatus*); Custard apple (*Annona reticulata*) + Satawar (*Asparagus racemosus*); and Pomegranate (*Punica granatum*) + Lampa grass (*Heteropogen contortus*).
- M4 (silvi-medicinal module): Multipurpose trees grown with medicinal plants included Khair (*Acacia catechu*) + Aloe vera (*Aloe barbadensis*); Karanj (*Pongamia pinnata*) + Satawar (*Asparagus racemosus*) + Lemongrass (*Cymbopogon citratus*); Guggal (*Commiphora wightii*) – Safed musli (*Chlorophytum arundinaceum*); Cotton tree (*Bombax ceiba*) – Ashwagandha (*Withania somnifera*); Bael (*Aegle marmelos*) – Castor (*Ricinus communis*); and Peelu (*Salvadora oleoides*) – Chandrasur (*Lepidium sativum*).
- M5 (silvopastoral module): Fodder grasses grown with multipurpose trees included Neem (*Azardirechta indica*) + Ginni grasses; Karanj (*Pongamia pinnata*) + Napier grass (*Pennisetum purpureum*); Khejri (*Prosopis cineraria*) + Marvel grass (*Dichanthium annulatum*); Arduso (*Ailanthus excelsa*) + Para grass (*Brachiaria mutica*); Siras (*Albizia lebbeck*) + Lampa grass (*Heteropogen contortus*); and Subabul (*Leucaena lencocephala*) + Anjan grass (*Cenchrus ciliaris*) [25].

6. Rainwater harvesting in urban and semi-urban areas

Rooftop Rainwater Harvesting : It is a technique wherein rainfall falling onto roof surfaces of houses, schools, colleges, offices and other establishments is diverted via a system of pipes and filter media to a storage tank or recharge underlying aquifer (by Manager Aquifer Recharge techniques). It also requires comparatively less maintenance for operation.

It prevents surplus rainfall from flowing into drains contributing to urban flooding in addition to checking soil erosion besides enhancing the groundwater levels, if not stored in a tank. When stored in a tank or sump, it can help tide over peak water demands during summer.

Amount of rainfall harvested depends on 3 factors –

(i) Quantum of annual Rainfall (mm)
(ii) Rooftop area (m^2)
(iii) Runoff factor (0.2 to 0.8 depending on roofing material)

Formula to calculate harvested rainfall = Quantum of annual Rainfall (mm)* Rooftop area (m^2)* Runoff factor

5.2 Demand side interventions

Agriculture is the major consumer of groundwater followed by domestic and industrial needs. There is increasing focus on promoting the use of micro-irrigation practices like sprinkler and drip irrigation as the traditional method of irrigation through canals results in lesser efficiency. The different interventions have been described below –

1. Promoting drip and sprinkler irrigation to enhance crop production.

- It will result in saving the quantum of groundwater applied for irrigation in addition to increasing the farmer's income as it will enable them to go in for one or two additional crops.
- Water losses are as low as 20 – 25% for Drip irrigation and 30 – 40% in Sprinkler irrigation.
- Drip irrigation is suitable for wide spaced crops in addition to irrigating oil seeds, pulses, cotton and wheat crops. Sprinkler irrigation is suitable for closely spaced crops such as fruits, vegetables, spices, flowers, sugarcane etc.
- There must be a thorough survey carried out by the concerned Department (Revenue/Agriculture/Land Holding etc.) to determine the land holdings of small and marginal farmers as majority of the micro-irrigation schemes are implemented on macro scale and most land holdings are small, about 1 hectare or lesser in most cases.

2. Development of new variety of pulses with high per hectare yield and promoting cultivation of pulses with incentives [26]

- India is the largest consumer of pulses and India largely being a vegetarian country meets only 11% of daily protein intake through consumption of pulses.
- India accounts for 27% of import of pulses from Canada and the shortfall is met from Myanmar, Australia and USA. The Indian government has banned the export of pulses to ensure availability to public.
- In addition to meeting protein intake, pulses also increase soil fertility through nitrogen fixing bacteria present in root system to the tune of 40 kg/Ha of Nitrogen. It

also provides agronomic benefit to the next crop in terms of better soil microenvironment, quality and yield.

- The soil type, agro-climatic conditions in Hamirpur district are conducive for cultivation of pulses mainly in Rabi and partly in Kharif seasons. The adoption of micro-irrigation techniques coupled with water and soil conservation measures will result in enhanced output of pulses and reduce the quantum of pulses to be imported.
- The cultivation of pulses can be given a fillip by integrating it with existing government schemes like Accelerated Pules Production programme and Pulses Development Programme under Rashtriya Krishi Vikas Yojana in addition to Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) scheme.
- Development of pulse varieties requiring low input of water and tolerant to drought conditions can be an alternative by collaboration of State Agricultural University with ICRISAT (International Crops Research Institute for Semi-Arid Tropics) and Directorate of Pulses Development at Bhopal. Rainfed Area Authority (RAA) can also play a pivotal role in this regard.
- The State agriculture department in collaboration with Agriculture University/KVK and NGO’s can sensitize farmers on benefits on cultivation of pulses as inter-crops and inclusion of short duration pulse varieties as cash crop through meetings etc.

3. Crop diversification by promoting the cultivation of oil seeds

- India is the second largest importer of oil seeds and the third largest consumer of oilseeds and an amount of ₹74,996 crores is spent on import (2017-18) since the production of oil seeds is insufficient to cater to the needs of the population and includes a 40% import duty.
- Doubling the import duty coupled with incentives to cultivate oilseeds indigenously by integrating Minimum Support Price (MSP) with Minimum Renumerative price (MRP) and according special status to oil seed sector by National Food Security Mission (NFSM) will prove beneficial to the country in the long run.
- Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) – Central government scheme wherein the State government draws up a Five year seed plan indicating the requirement of each farmer and ICAR has been nominated as the nodal agency. ICAR has the responsibility for procurement and distribution of seeds, weedicides/bio-pesticides, distribution of Gypsum/Pyrite/Liming/Dolomite for lining soils and sprinkler sets in addition to ensuring infrastructural support, technical training to farmers and demonstration of latest agricultural inputs to boost yield.
- The oilseeds covered under this scheme are Groundnuts, Soyabean, Mustard, Rapseed, Sunflower, Sesamum, Safflower, Niger, Castor and Linseed that can be cultivated on suitable soils as decided by State Agricultural Universities [27].

6. BLOCK WISE MANAGEMENT PLANS

6.1 Management Plan for Maudaha block

The geographical area of Maudaha block is 651.36 km^2 and Groundwater development as per GEC-2015 is 80.22% and is categorised as Semi-Critical. The annual groundwater resource available is 46.4250 MCM and the current groundwater extraction for all uses is 37.2439 MCM, of which 32.0180 MCM is for irrigation purpose, 5.2259 MCM is for domestic & industrial use. Net groundwater availability for future use is 6.9053 MCM. The major issues identified in Maudaha block include limited granular zones for groundwater extraction, over-use of groundwater for irrigation, erratic rainfall coupled with recurring droughts and shallow depths of tubewells owing to encountering basement at shallow depth.

Supply side interventions to tackle the aforesaid issues include Rooftop Rainwater Harvesting in urban & semi-urban areas alongside construction of Managed Aquifer Recharge structures. 5 Nos. of Check dams of 10,000m^3, 10 Nos. of Nala bunds of 7,500m^3 and desilting of 30 Nos. of village ponds of 10,000m^3 has been proposed. 4.48 MCM of groundwater savings are expected as a result of these interventions in addition to 4.64 MCM of groundwater recharge.

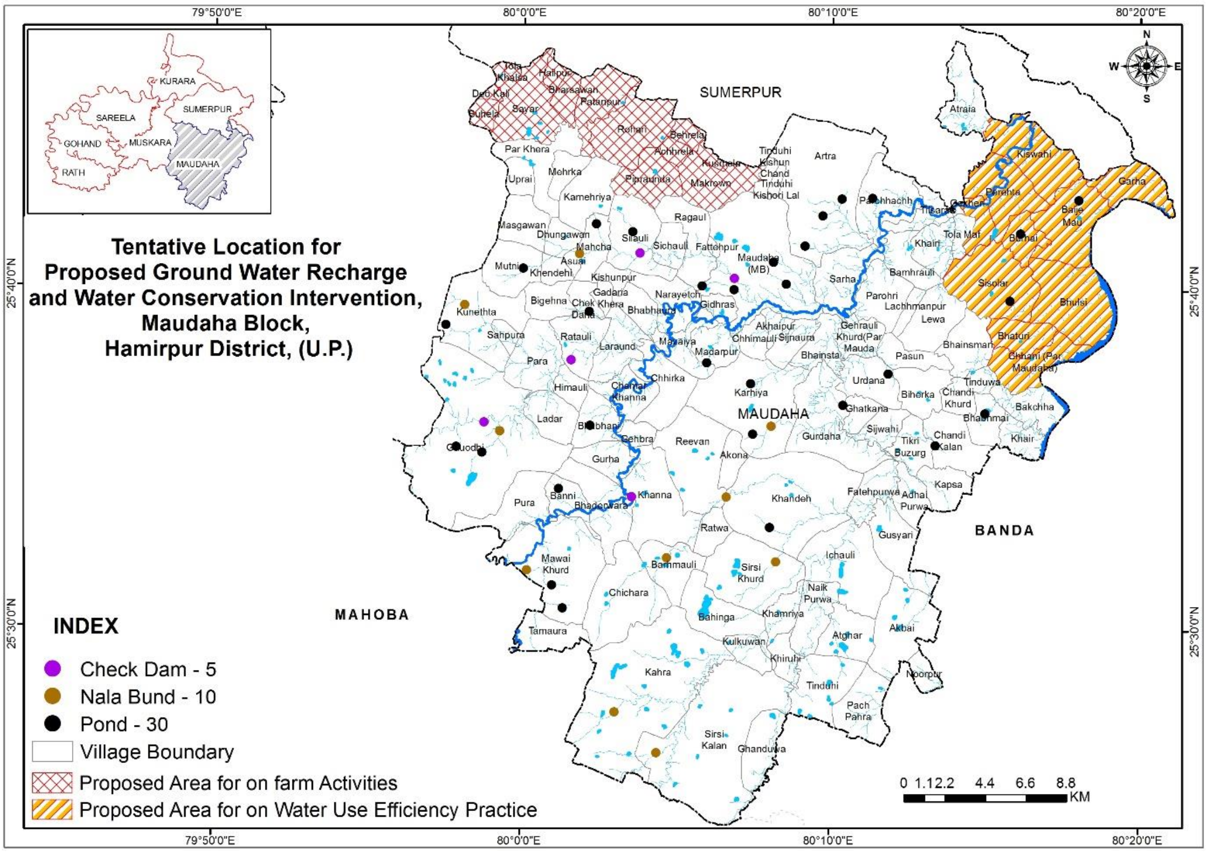

Figure 27: Supply side interventions proposed in Maudaha block

Demand side interventions include promoting pressurized irrigation systems like Drip and Sprinkler irrigation, development of new variety of wheat crop requiring less input of water, promoting the cultivation of pulses and oilseeds coupled with subsidies. Geographical areas of 4,000 Ha and 3,876 Ha have been identified for demand side interventions and is expected to lessen the burden on groundwater by 0.0192 MCM.

As a result of both supply side and demand interventions, the expected benefits are summarized below –

1. Stage of Groundwater Development is expected to become 64.16% from 80.22%.

2. About 0.64 MCM of groundwater will be available for supplemental irrigation upon adoption of suitable recharge measures.

3. Total groundwater storage in various M.A.R structures is expected to be about 1.28 MCM, which can be utilized for either irrigation or domestic purposes.

6.2 Management plan for Muskara block

The geographical area of Muskara block is 513.98 km^2 and Groundwater development as per GEC-2015 is 49.48% and is categorised as Safe. The annual groundwater resource available is 78.1644 MCM and the current groundwater extraction for all uses is 38.6756 MCM, of which 35.4760 MCM is for irrigation purpose, 3.1996 MCM is for domestic & industrial use. Net groundwater availability for future use is 38.6953 MCM. The major issues identified in Muskara block include limited granular zones for groundwater extraction, over-use of groundwater for irrigation, erratic rainfall coupled with recurring droughts and shallow depths of tubewells owing to encountering basement at shallow depth.

Supply side interventions to tackle the aforesaid issues include Rooftop Rainwater Harvesting in urban & semi-urban areas alongside construction of Managed Aquifer Recharge structures. 10 Nos. of Check dams of 10,000m^3, 20 Nos. of Nala bunds of 7,500m^3 and desilting of 50 Nos. of village ponds of 10,000m^3 has been proposed. 5.38 MCM of groundwater savings are expected as a result of these interventions in addition to 7.55 MCM of groundwater recharge.

Demand side interventions include promoting pressurized irrigation systems like Drip and Sprinkler irrigation, development of new variety of wheat crop requiring less input of water, promoting the cultivation of pulses and oilseeds coupled with subsidies. Geographical areas of 6,423 Ha and 6,784 Ha have been identified for demand side interventions and is expected to lessen the burden on groundwater by 0.0213 MCM.

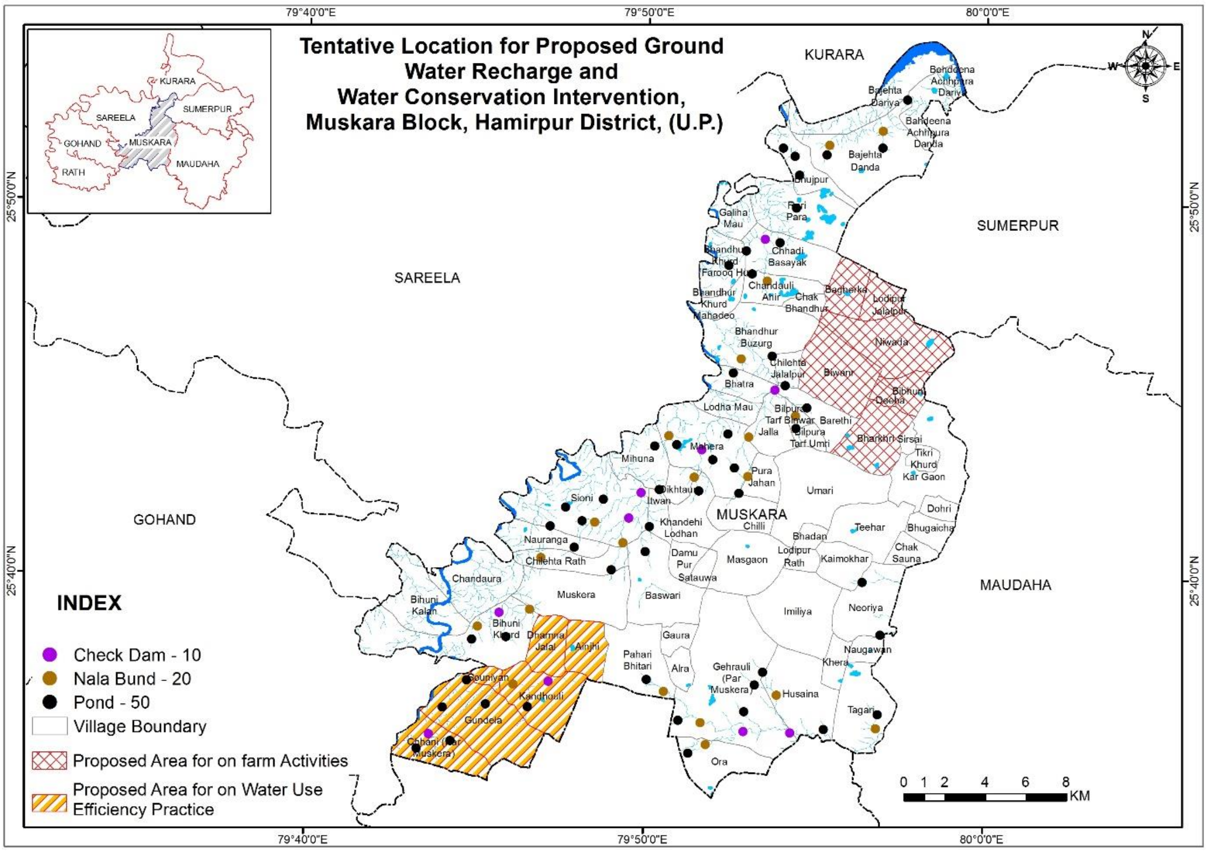

Figure 28: Supply side interventions proposed in Muskara block

As a result of both supply side and demand interventions, the expected benefits are summarized below –

1. Stage of Groundwater Development is expected to become 49.48% from 38.84%.

2. About 1.13 MCM of groundwater will be available for supplemental irrigation upon adoption of suitable recharge measures.

3. Total groundwater storage in various M.A.R structures is expected to be about 2.25 MCM, which can be utilized for either irrigation or domestic purposes.

6.3 Management plan for Sarila block

The geographical area of Sarila block is 670.68 km^2 and Groundwater development as per GEC-2015 is 78.83% and is categorised as Semi-Critical. The annual groundwater resource available is 55.2324 MCM and the current groundwater extraction for all uses is 38.6756 MCM, of which 40.8504 MCM is for irrigation purpose, 2.6882 MCM is for domestic & industrial use. Net groundwater availability for future use is 11.3168 MCM. The major issues identified in Sarila block include limited granular zones for groundwater extraction, over-use of groundwater for irrigation, erratic rainfall coupled with recurring droughts.

Supply side interventions to tackle the aforesaid issues include Rooftop Rainwater Harvesting in urban & semi-urban areas alongside construction of Managed Aquifer Recharge structures. 10 Nos. of Check dams of 10,000m^3, 20 Nos. of Nala bunds of 7,500m^3 and desilting of 50 Nos. of village ponds of 10,000m^3 has been proposed. 6.03 MCM of groundwater savings are expected as a result of these interventions in addition to 9.17 MCM of groundwater recharge.

Demand side interventions include promoting pressurized irrigation systems like Drip and Sprinkler irrigation, development of new variety of wheat crop requiring less input of water, promoting the cultivation of pulses and oilseeds coupled with subsidies. Geographical areas of 8,048 Ha and 5,834 Ha have been identified for demand side interventions and is expected to lessen the burden on groundwater by 0.0245 MCM.

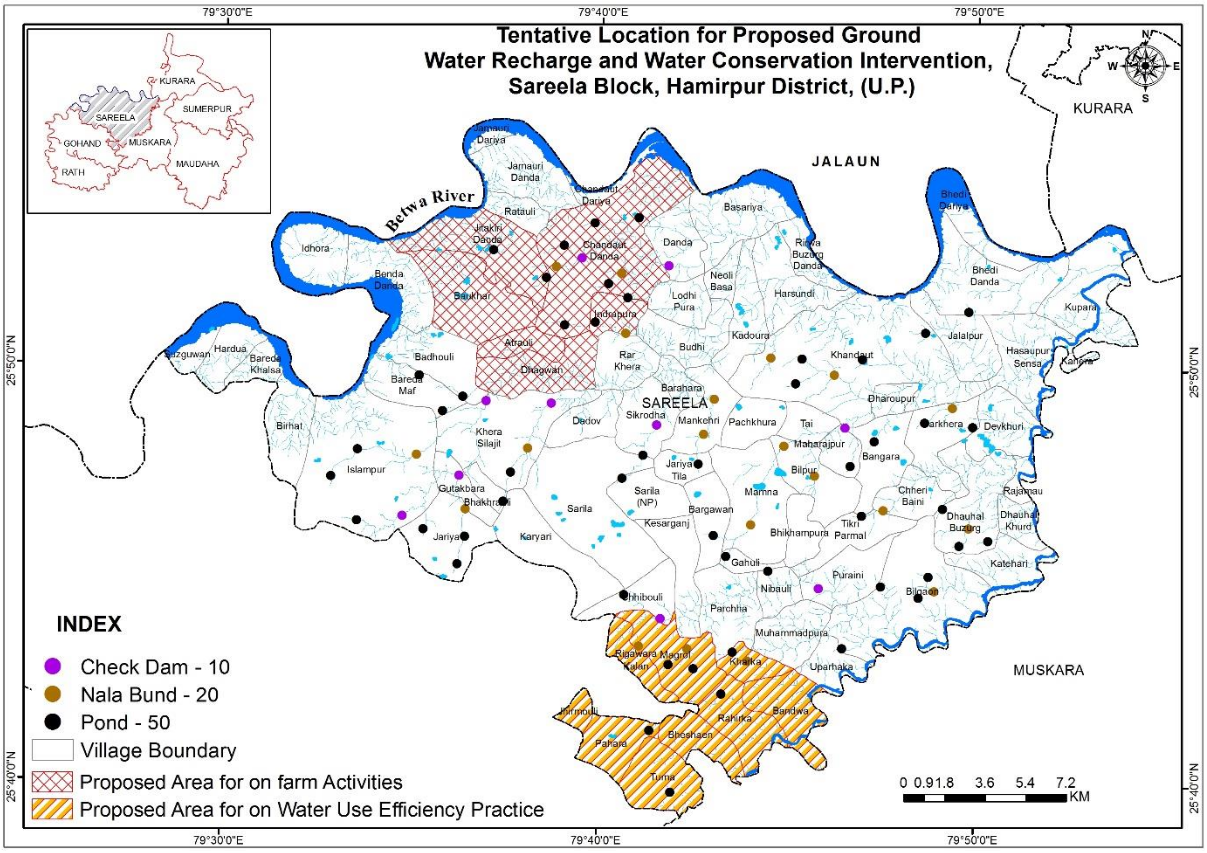

Figure 29: Supply side interventions proposed in Sarila block

As a result of both supply side and demand interventions, the expected benefits are summarized below –

1. Stage of Groundwater Development is expected to become 78.83% from 58.24%.

2. About 1.13 MCM of groundwater will be available for supplemental irrigation upon adoption of suitable recharge measures.

3. Total groundwater storage in various M.A.R structures is expected to be about 2.25 MCM, which can be utilized for either irrigation or domestic purposes.

6.4 Management plan for Sumerpur block

The geographical area of Sumerpur block is 589.97 km^2 and Groundwater development as per GEC-2015 is 83.75% and is categorised as Semi-Critical. The annual groundwater resource available is 74.4308 MCM and the current groundwater extraction for all uses is 62.3376 MCM, of which 56.5760 MCM is for irrigation purpose, 5.7616 MCM is for domestic & industrial use. Net groundwater availability for future use is 12.0322 MCM. The major issues identified in Sumerpur block include limited granular zones for groundwater extraction, over-use of groundwater for irrigation, erratic rainfall coupled with recurring droughts.

Supply side interventions to tackle the aforesaid issues include Rooftop Rainwater Harvesting in urban & semi-urban areas alongside construction of Managed Aquifer Recharge structures. 10 Nos. of Check dams of 10,000m^3, 20 Nos. of Nala bunds of 7,500m^3 and desilting of 50 Nos. of village ponds of 10,000m^3 has been proposed. 6.03 MCM of groundwater savings are expected as a result of these interventions in addition to 9.17 MCM of groundwater recharge.

Demand side interventions include promoting pressurized irrigation systems like Drip and Sprinkler irrigation, development of new variety of wheat crop requiring less input of water, promoting the cultivation of pulses and oilseeds coupled with subsidies. Geographical areas of 7,080 Ha and 5,310 Ha have been identified for demand side interventions and is expected to lessen the burden on groundwater by 0.0339 MCM.

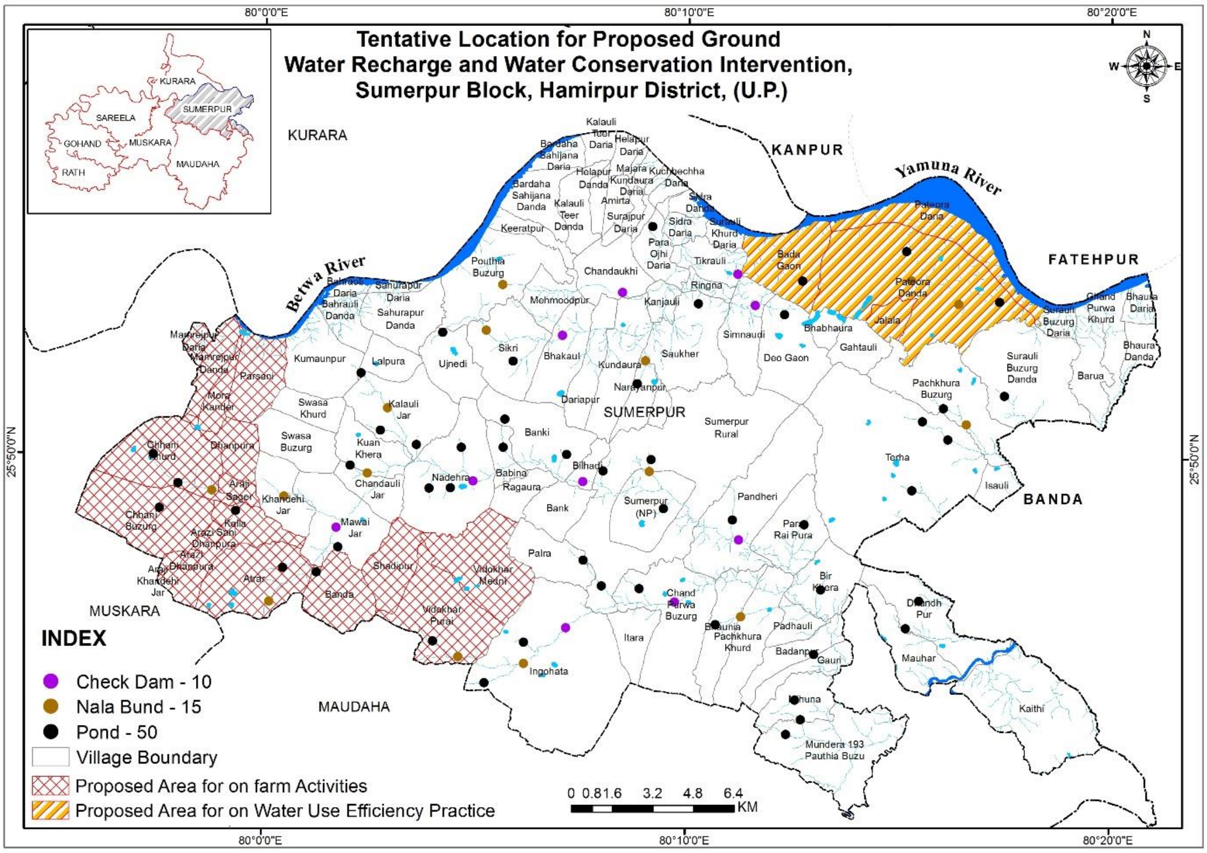

Figure 30: Supply side interventions proposed in Sumerpur block

As a result of both supply side and demand interventions, the expected benefits are summarized below –

1. Stage of Groundwater Development is expected to become 65.97% from 83.75%.

2. About 1.07 MCM of groundwater will be available for supplemental irrigation upon adoption of suitable recharge measures.

3. Total groundwater storage in various M.A.R structures is expected to be about 2.14 MCM, which can be utilized for either irrigation or domestic purposes.

7. CONCLUSION

The district occupies a geographic area of 4,021 km^2 and is divided into 7 administrative blocks. The population of the district is 11,04,285 and population density is 275 people per square kilometres. The district mainly comprises of Quaternary alluvium underlain by consolidated rocks of Bundelkhand Granite.

Due to the geological and geomorphological setup of the district, the groundwater resources are limited, both in quality and quantity. The thickness of alluvium decreases from the northern portion of the district towards the southern portion, resulting in reduction of potential granular zones alongside reduced discharge from shallow depths of tubewells. Portions of the district display problems in groundwater quality relating mainly to salinity and Fluoride. Other problems include over-use of groundwater for irrigation, erratic rainfall coupled with prolonged periods of drought.

Surface water utilization has decreased over the years due to ease in availability of groundwater for domestic, irrigation and industrial purposes.

To augment stressed groundwater resources, address declining groundwater levels and water quality problems, the following interventions have been proposed.

Supply side interventions proposed include –

1. Construction and maintenance of Managed Aquifer Recharge structures viz. Dams/ponds/percolation tanks/gabion structures etc.

2. Carrying out de-siltation of streams, ponds, tanks and surface water catchments to increase storage.

3. Large scale afforestation measures to capture soil moisture by transplantation of local species.

4. Increasing greenery in ravines for carbon sequestration and combating climate change

5. Construction of Rainwater harvesting structures at suitable locations.

Demand side interventions proposed include –

1. Promotion of drip and sprinkler/pressurized irrigation to enhance irrigation efficiency as opposed to traditional flood irrigation method.

2. Development of new variety of pulses with high per hectare yield and promoting cultivation of pulses with incentives.

3. Diversification of cropping pattern to promote cultivation of oil seeds.

4. Development of new variety of wheat that requires less input of water.

5. Measures to decrease evapotranspiration losses.

Apart from Demand side and Supply side interventions, IEC activities must be stepped up that promote emerging farming techniques, water use efficiency techniques, crop rotation etc. A proposal can also be drawn up to explore the groundwater potential in the basement rocks belonging to Bundelkhand Craton.

ANNEXURE – 1

(RAINFALL DATA OF HAMIRPUR DISTRICT)

Year	Total Rainfall (mm)	Year	Total Rainfall (mm)	Year	Total Rainfall (mm)
1971	1,029.10	1991	796.34	2011	988.38
1972	652.60	1992	862.58	2012	820.07
1973	527.99	1993	842.31	2013	1,185.97
1974	682.26	1994	864.19	2014	754.92
1975	925.23	1995	713.41	2015	809.09
1976	948.03	1996	909.05	2016	859.44
1977	931.28	1997	1,079.32	2017	416.00
1978	1,138.83	1998	733.80	2018	820.11
1979	582.64	1999	1,437.70	2019	947.45
1980	1,534.33	2000	715.86		
1981	723.42	2001	744.39		
1982	1,178.57	2002	697.17		
1983	911.80	2003	979.97		
1984	646.02	2004	784.54		
1985	967.92	2005	897.55		
1986	633.79	2006	626.93		
1987	769.43	2007	519.72		
1988	757.21	2008	941.53		
1989	554.84	2009	612.11		
1990	859.11	2010	707.36		

ANNEXURE – 2
(BASIC GW QUALITY DATA OF UNCONFINED AQUIFER)

Sl. No.	Village	Block	pH	TDS	EC	HCO_3	CO_3	Cl	SO_4	NO_3	Ca	Mg	Na	K	F	HCF*
1	Kundaura	Sumerpur	7.83	507.78	819	323.3	0	74.32	33.30	16.40	42.08	32.82	76.93	2.42	0.80	Mg-HCO3
2	Terha	Sumerpur	7.96	428.42	691	427.0	0	16.89	6.70	10.80	74.15	32.78	36.54	8.88	1.00	Mg-HCO3
3	Surauli Buzurg	Sumerpur	7.88	385.64	622	372.1	0	16.89	7.20	0.00	42.08	27.95	57.69	2.43	0.70	Mg-HCO3
4	Para Rai Pura	Sumerpur	7.67	510.88	824	469.7	0	37.16	6.20	10.30	42.08	48.65	71.34	1.86	0.90	Mg-HCO3
5	Mihuna	Sumerpur	7.89	503.44	812	457.5	0	37.16	18.90	13.90	36.07	32.83	93.07	0.98	0.80	Mg-HCO3
6	Pachkura	Sumerpur	7.89	468.10	755	347.7	0	54.05	15.80	29.75	42.08	42.56	59.91	1.18	1.00	Mg-HCO3
7	Chandaukh i	Sumerpur	7.8	522.66	843	353.8	0	64.19	25.00	19.25	64.13	25.49	86.30	1.18	0.90	Mg-HCO3
8	Nazarpur	Sumerpur	8.38	1195.98	1929	1091.9	60	33.78	27.20	15.80	30.06	21.88	470.00	0.81	1.20	Na-HCO3
9	Sumerpur	Sumerpur	8.23	610.70	985	457.5	30	60.81	23.40	11.90	76.15	32.78	101.10	1.15	1.20	Mg-HCO3
10	Chan Purwa	Sumerpur	8.56	436.48	704	372.1	78	20.27	5.20	0.60	16.03	41.38	100.00	0.77	1.00	Mixed
11	Ingohta	Sumerpur	8.05	751.44	1212	445.3	0	67.57	48.20	18.25	44.09	60.82	95.50	1.00	1.00	Mg-HCO3
12	Vidokhar Medni	Sumerpur	7.97	522.66	843	494.1	0	20.27	15.70	5.20	42.08	41.34	81.23	0.78	0.90	Mg-HCO3
13	Mawai Jar	Sumerpur	8.17	666.50	1075	610.0	0	54.05	19.40	7.70	26.05	34.06	207.50	0.95	1.00	Na-HCO3
14	Nadehra	Sumerpur	7.94	550.56	888	408.7	0	84.46	17.80	6.60	52.10	57.16	63.15	0.83	0.60	Mg-HCO3
15	Atrar	Sumerpur	8.38	345.34	557	280.6	30	16.89	6.90	12.40	28.06	32.84	54.06	0.69	0.60	Mg-HCO3
16	Channi Buzurg	Sumerpur	8.05	575.36	928	488.0	0	60.81	18.00	13.70	40.08	60.83	89.34	0.98	0.80	Mg-HCO3
17	Dhanpura (Kalla)	Sumerpur	8.37	376.96	608	268.4	54	16.89	9.90	0.50	26.05	57.19	34.52	1.34	0.90	Mg-HCO3
18	Swasa Buzurg	Sumerpur	8.17	553.04	892	530.7	0	20.27	6.80	13.60	34.07	54.75	83.92	1.00	1.00	Mg-HCO3
19	Lalpura	Sumerpur	8.76	1050.90	1695	872.3	114	60.81	7.90	10.40	4.01	58.44	389.50	0.69	1.00	Na-HCO3
20	Ujnedi	Sumerpur	7.82	2360.96	3808	542.9	0	625.00	506.00	345.00	116.23	215.36	500.00	7.23	1.20	Mixed
21	Pouthia	Sumerpur	8.46	572.88	924	475.8	60	20.27	11.40	8.10	36.07	41.35	113.44	1.14	0.90	Mg-HCO3
22	Chandulee Teer	Sumerpur	7.91	469.96	758	390.4	0	20.27	1.90	17.70	68.14	24.27	59.65	0.87	0.60	Mg-HCO3
23	Sarseda Maf	Gohand	8.09	1106.70	1785	646.6	0	104.73	127.44	130.50	22.04	92.50	242.00	1.75	1.21	Mixed
24	Aunta	Gohand	8.1	734.70	1185	506.3	0	70.95	35.12	9.50	44.09	27.95	164.00	1.01	0.71	Mixed
25	Sarsai	Gohand	7.95	582.80	940	408.7	0	54.05	32.20	13.80	54.11	38.89	77.63	4.80	0.63	Mg-HCO3
26	Umariya	Gohand	8.38	438.34	707	286.7	42	33.78	7.41	0.00	14.03	41.38	76.77	2.13	0.53	Mg-HCO3
27	Pawai	Gohand	7.65	789.88	1274	347.7	0	158.78	84.76	0.00	40.08	31.61	179.00	1.18	0.66	Na-Cl
28	Alkachaba	Gohand	7.65	707.42	1141	439.2	0	91.22	25.48	47.00	46.09	63.25	43.71	61.80	0.52	Mg-HCO3
29	Amond	Gohand	8.04	451.36	728	396.5	0	10.14	2.57	4.10	14.03	20.68	110.35	0.66	0.90	Na-HCO3
30	Jarakhar	Gohand	7.27	437.72	706	384.3	0	23.65	3.29	0.00	32.06	25.53	77.22	1.16	0.50	Mg-HCO3
31	Tyontana	Gohand	7.82	341.00	550	311.1	0	16.89	0.65	2.00	8.02	35.30	54.35	1.10	0.73	Mg-HCO3
32	Iteliya Bazar	Gohand	7.98	295.12	476	207.4	0	23.65	1.62	10.80	30.06	21.88	30.78	1.05	0.40	Mg-HCO3
33	Bilgaon	Gohand	7.82	406.72	656	366.0	0	16.89	1.53	3.00	40.08	29.17	58.33	0.94	0.58	Mg-HCO3
34	Gohand	Gohand	7.86	416.02	671	378.2	0	16.89	1.34	2.70	30.06	36.49	56.40	0.98	0.59	Mg-HCO3
35	Rawatpura	Gohand	7.92	366.42	591	323.3	0	16.89	3.00	7.40	44.09	27.95	44.21	0.90	0.63	Mg-HCO3
36	Churha	Gohand	7.86	407.96	658	353.8	0	16.89	1.77	7.20	44.09	27.95	55.28	0.86	0.68	Mg-HCO3
37	Bargar	Gohand	7.8	407.96	658	378.2	0	10.14	0.76	8.70	52.10	6.02	67.49	0.67	0.90	Mg-HCO3
38	Atrar	Gohand	7.89	351.54	567	335.5	0	16.89	1.36	5.00	44.09	25.51	44.01	0.93	0.75	Mg-HCO3
39	Magrauth	Gohand	7.74	368.90	595	384.3	0	13.51	1.32	4.80	50.10	26.72	48.80	0.80	0.77	Mg-HCO3
40	Chikasi	Gohand	7.75	396.80	640	359.9	0	23.65	1.03	6.20	46.09	27.95	52.59	0.84	0.66	Mg-HCO3
41	Sarsai	Kurara	8.48	676.42	1091	555.1	60	13.51	1.82	7.60	20.04	30.41	178.80	0.63	1.64	Na-HCO3

42	Kutubpur	Kurara	7.96	421.60	680	390.4	0	13.51	0.00	3.80	34.07	31.61	59.42	1.44	0.76	Mg-HCO3
43	Simra	Kurara	8.69	1220.16	1968	786.9	138	84.46	46.75	18.50	4.01	52.35	340.24	1.74	1.05	Na-HCO3
44	Bramha ka Dera	Kurara	8.04	249.86	403	183.0	0	13.51	4.32	6.90	48.10	7.25	8.74	1.14	0.59	Mg-HCO3
45	Chandupur Danda	Kurara	7.92	601.40	970	433.1	0	40.54	27.95	24.40	34.07	37.70	83.98	1.41	0.68	Mg-HCO3
46	Kusmara	Kurara	7.84	411.68	664	274.5	0	33.78	15.64	11.10	48.10	19.42	38.26	4.69	0.60	Mg-HCO3
47	Patara	Kurara	8.04	810.96	1308	725.9	0	43.92	3.20	1.70	16.03	47.46	170.23	1.43	0.83	Na-HCO3
48	Jhalokhar	Kurara	7.91	655.96	1058	518.5	0	37.16	14.26	54.75	22.04	73.02	67.17	2.55	1.09	Mg-HCO3
49	Raghwa	Kurara	8.29	335.42	541	237.9	18	23.65	8.71	1.10	12.02	30.42	40.85	1.27	0.65	Mg-HCO3
50	Shekhoopur	Kurara	8.08	647.28	1044	555.1	0	27.03	6.53	5.90	18.04	32.85	128.42	1.85	0.81	Na-HCO3
51	Bachrauli	Kurara	7.93	514.60	830	445.3	0	16.89	0.71	8.30	20.04	46.24	68.51	2.10	0.61	Mg-HCO3
52	Sikodi	Kurara	8.41	407.96	658	317.2	30	13.51	7.40	7.70	6.01	34.08	72.42	1.89	0.73	Mixed
53	Bhauli	Kurara	8.05	510.26	823	445.3	0	16.89	10.45	4.10	16.03	30.42	93.21	2.01	0.68	Mixed
54	Jakhela	Kurara	7.99	729.12	1176	384.3	0	77.70	104.45	17.80	26.05	37.71	128.53	1.28	0.67	Mixed
55	Jhalla	Kurara	8.49	1023.00	1650	957.7	54	16.89	36.60	1.00	6.01	47.48	305.75	10.39	0.72	Na-HCO3
56	Rithari	Kurara	8.32	726.64	1172	628.3	36	30.41	18.00	7.00	18.04	43.81	168.54	1.34	0.68	Na-HCO3
57	Kurara	Kurara	8.08	421.60	680	366.0	0	16.89	2.31	4.00	20.04	23.11	72.34	1.32	0.64	Mixed
58	Hamirpur	Kurara	8.08	797.32	1286	488.0	0	94.59	73.70	27.20	18.04	59.64	132.42	2.89	0.74	Mixed
59	Khanna	Maudaha	7.62	7332.00	12220	402.6	0	3580.45	1780.00	13.80	476.95	294.06	1925.00	8.96	1.90	Na-Cl
60	Artara	Maudaha	8.56	647.90	1045	298.9	48	91.22	77.04	0.00	40.08	41.35	110.33	0.75	1.45	Mg-HCO3
61	Parchhachh	Maudaha	8.21	672.08	1084	536.8	0	33.78	38.84	9.30	14.03	20.68	212.00	0.76	1.40	Na-HCO3
62	Sisolar	Maudaha	8.23	383.16	618	347.7	0	16.89	3.66	6.40	10.02	31.64	78.94	0.98	1.39	Mixed
63	Bhulsi	Maudaha	7.92	823.36	1328	549.0	0	94.59	47.58	13.30	38.08	27.96	216.00	1.36	1.19	Mixed
64	Bhainsmari	Maudaha	8.58	1395.00	2250	890.6	72	101.35	108.72	18.20	12.02	32.86	491.00	0.94	2.62	Na-HCO3
65	Chahani Par	Maudaha	8.19	2839.60	4580	1006.5	0	358.11	1592.00	1.80	38.08	82.74	1052.00	1.66	2.66	Na-Cl
66	Bhabhamai	Maudaha	8.41	1723.60	2780	957.7	66	70.95	356.10	0.40	16.03	34.07	602.00	1.06	3.04	Na-HCO3
67	Biherka	Maudaha	8.45	2356.00	3800	939.4	72	209.46	692.00	10.20	12.02	51.12	855.00	2.11	3.26	Na-Cl
68	Tikri Buzurg	Maudaha	8.3	576.60	930	402.6	30	16.89	28.99	24.20	34.07	26.74	105.54	7.79	1.45	Mixed
69	Kapsa	Maudaha	7.94	3124.80	5040	427.0	0	675.68	1082.50	25.40	80.16	47.39	1041.00	4.96	2.92	Na-Cl
70	Ghatkana	Maudaha	8.94	699.36	1128	390.4	126	16.89	29.71	9.80	4.01	13.39	268.00	1.64	1.93	Na-HCO3
71	Bhainsta	Maudaha	7.74	1049.04	1692	280.6	0	337.84	51.66	2.10	106.21	58.31	107.09	2.76	0.97	Mixed
72	Karhiya	Maudaha	8.38	1240.00	2000	158.6	42	375.00	209.40	6.70	46.09	104.65	187.00	3.69	1.37	Mixed
73	Khandeh	Maudaha	7.54	7303.60	11780	366.0	0	3206.09	1268.00	0.30	366.73	262.53	1916.00	8.08	2.66	Na-Cl
74	Bhawani	Maudaha	8.08	761.98	1229	603.9	0	67.57	28.29	5.90	16.03	35.29	224.00	2.96	1.14	Na-HCO3
75	Chhirka	Maudaha	7.99	525.76	848	439.2	0	33.78	11.80	15.20	38.08	27.96	91.67	2.38	1.18	Mg-HCO3
76	Madarpura	Maudaha	8.46	1210.86	1953	549.0	60	199.32	100.00	0.80	10.02	19.47	421.00	2.40	1.52	Mixed
77	Bhamaura	Maudaha	8.32	2777.60	4480	298.9	18	844.60	695.60	0.20	108.22	80.22	828.00	4.03	3.04	Na-Cl
78	Madudaha	Maudaha	7.61	2387.00	3850	359.9	0	614.87	601.00	0.00	108.22	55.87	662.00	2.77	1.60	Na-Cl
79	Makrown	Maudaha	8.01	749.58	1209	518.5	0	87.84	62.90	9.20	52.10	27.94	198.00	1.50	0.90	Mixed
80	Pipraunda	Maudaha	7.9	1723.60	2780	567.3	0	263.51	363.10	158.00	76.15	15.73	558.00	1.44	1.00	Na-Cl
81	Patanpura	Maudaha	7.84	364.56	588	323.3	0	16.89	4.04	7.50	54.11	21.85	37.20	0.65	0.70	Mg-HCO3
82	Silauli	Maudaha	8.07	937.44	1512	530.7	0	101.35	101.96	2.70	26.05	21.88	274.00	1.12	1.02	Mixed
83	Kamehriya	Maudaha	7.61	1223.88	1974	341.6	0	378.38	105.60	0.00	86.17	133.82	72.89	2.50	0.61	Ca-Cl2
84	Sayar	Maudaha	7.51	4947.60	7980	146.4	0	2422.30	479.40	0.00	418.84	201.60	1072.00	5.98	1.42	Na-Cl
85	Bharsawan	Maudaha	8.32	1308.20	2110	494.1	42	270.27	95.64	42.00	32.06	19.44	426.00	0.91	2.50	Na-Cl
86	Ramna Kishanpur	Maudaha	7.86	1512.80	2440	408.7	0	320.95	330.10	12.60	62.12	82.71	342.00	1.41	1.10	Na-Cl

87	Asuai	Maudaha	8.35	1052.14	1697	701.5	78	54.05	72.60	11.50	28.06	15.79	372.00	0.54	1.60	Na-HCO3
88	Masgawan	Maudaha	8.25	559.24	902	439.2	0	20.27	24.72	37.50	32.06	23.09	106.00	1.39	1.10	Mixed
89	Laraund	Maudaha	8.39	1754.60	2830	433.1	60	425.68	226.90	40.00	10.02	40.17	558.00	2.35	1.44	Na-Cl
90	Ratauli	Maudaha	8.18	2064.60	3330	762.5	0	388.51	399.70	4.20	24.05	46.24	688.00	1.42	1.76	Na-Cl
91	Para	Maudaha	8.45	1150.72	1856	725.9	66	101.35	92.34	20.60	8.02	18.25	441.00	0.79	1.60	Na-HCO3
92	Chak Daha	Maudaha	8.14	737.80	1190	634.4	0	33.78	25.80	6.30	12.02	35.29	217.00	0.97	1.00	Na-HCO3
93	Ruri Para	Muskara	8.28	610.08	984	372.1	30	33.78	8.00	6.30	28.06	34.06	88.97	0.83	0.80	Mg-HCO3
94	Lodhipur Niwada	Muskara	8.32	583.42	941	359.9	48	47.30	16.39	24.40	28.06	55.97	97.00	0.89	1.43	Mg-HCO3
95	Binawar	Muskara	7.84	987.04	1592	549.0	0	108.11	55.84	157.00	40.08	81.52	184.00	0.87	0.83	Mg-HCO3
96	Bhandkhur Khurd	Muskara	7.95	608.22	981	500.2	0	40.54	16.65	6.10	38.08	46.22	101.31	4.18	1.22	Mg-HCO3
97	Bajehata	Muskara	8.26	503.44	812	390.4	30	20.27	13.31	7.10	54.11	35.24	75.24	0.84	1.27	Mg-HCO3
98	Neoriya	Muskara	7.98	908.30	1465	542.9	0	118.24	11.28	10.25	32.06	70.58	142.00	1.93	1.47	Mg-HCO3
99	Husaina	Muskara	8.17	911.40	1470	701.5	0	81.08	28.73	13.20	22.04	65.72	218.00	1.80	1.49	Mixed
100	Basauth	Muskara	6.72	402.00	670	140.3	0	60.27	38.40	114.00	62.12	15.75	55.96	1.30	0.86	Mixed
101	Gehrauli	Muskara	7.98	571.64	922	420.9	0	50.68	28.69	10.60	30.06	63.27	58.00	2.48	1.26	Mg-HCO3
102	Muskeda	Muskara	7.94	880.40	1420	524.6	0	131.76	39.26	50.00	36.07	85.18	100.56	3.92	1.30	Mg-HCO3
103	Baswari	Muskara	7.98	1187.92	1916	549.0	0	165.54	62.12	227.00	24.05	59.63	328.00	1.40	1.36	Mixed
104	Masgaon	Muskara	8.07	512.74	827	481.9	0	13.51	1.36	6.00	28.06	43.80	76.32	0.96	1.79	Mg-HCO3
105	Khandehi Lodhan	Muskara	8.14	445.78	719	396.5	0	13.51	6.22	6.70	26.05	41.36	58.72	1.18	1.36	Mg-HCO3
106	Chilli	Muskara	7.82	916.36	1478	366.0	0	121.62	42.64	208.00	84.17	52.25	94.11	26.95	1.15	Mg-HCO3
107	Jalla	Muskara	7.99	425.94	687	335.5	0	23.65	18.68	8.20	26.05	43.80	41.33	0.95	1.17	Mg-HCO3
108	Bibhuni	Muskara	7.97	450.12	726	366.0	0	27.03	9.99	10.30	28.06	43.80	47.62	0.89	1.94	Mg-HCO3
109	Bharkhari	Muskara	7.61	3596.00	5800	305.0	0	810.81	458.20	699.00	254.51	193.27	561.00	15.00	2.22	Mixed
110	Kar Gaon	Muskara	7.9	541.26	873	378.2	0	54.05	24.76	7.40	70.14	23.05	69.16	1.93	1.28	Mg-HCO3
111	Teehar	Muskara	8.2	873.58	1409	518.5	0	101.35	77.12	26.30	20.04	20.67	275.00	0.53	1.81	Mixed
112	Mahera	Muskara	8.08	553.04	892	488.0	0	27.03	12.19	2.20	50.10	14.55	107.10	1.07	1.12	Mixed
113	Bhartra	Muskara	7.95	535.06	863	451.4	0	33.78	18.54	7.70	30.06	36.49	94.65	0.89	1.29	Mg-HCO3
114	Mihuna	Muskara	7.93	496.00	800	372.1	0	30.41	13.87	19.50	28.06	25.53	99.21	0.97	1.47	Mixed
115	Chandaura	Muskara	7.76	331.08	534	274.5	0	20.27	3.86	2.90	40.08	19.43	46.21	0.92	1.32	Mg-HCO3
116	Ainjhi	Muskara	7.95	1531.40	2470	689.3	0	233.11	151.30	77.50	36.07	131.45	185.00	141.60	2.20	Mg-HCO3
117	Gundela	Muskara	8.48	947.98	1529	671.0	60	20.27	100.76	10.40	32.06	20.66	309.00	0.66	2.20	Na-HCO3
118	Bihuni Khurd	Muskara	8.36	463.76	748	329.4	36	27.03	8.21	9.20	34.07	20.66	91.20	0.48	1.96	Mixed
119	Dhamna	Rath	7.79	1013.70	1635	738.1	0	162.16	29.10	30.80	12.02	68.17	265.90	1.98	1.26	Mixed
120	Dadri	Rath	8.47	1111.66	1793	231.8	12	37.16	12.87	22.20	26.05	51.10	21.47	0.65	1.09	Mg-HCO3
121	Tikaria	Rath	7.42	579.60	966	622.2	0	28.36	4.60	15.40	74.15	57.13	65.08	1.29	0.22	Mg-HCO3
122	Gohani Rath	Rath	7.89	446.40	720	402.6	0	20.27	3.94	8.20	36.07	36.48	75.34	0.82	1.07	Mg-HCO3
123	Badanpura	Rath	7.93	370.14	597	292.8	0	20.27	9.22	13.20	40.08	29.17	43.27	0.72	1.16	Mg-HCO3
124	Shuklahari	Rath	8.32	535.68	864	420.9	48	23.65	2.27	0.00	22.04	69.37	66.58	0.74	1.01	Mg-HCO3
125	Mawai	Rath	8.53	470.58	759	225.7	84	27.03	4.11	4.90	16.03	52.33	68.52	1.37	1.07	Mg-HCO3
126	Odera	Rath	8.32	419.12	676	341.6	24	16.89	3.37	4.60	32.06	53.53	25.98	0.66	0.89	Mg-HCO3
127	Kaintha	Rath	8.38	357.74	577	274.5	42	13.51	3.44	1.60	60.12	27.93	23.24	0.84	1.07	Mg-HCO3
128	Basela	Rath	8.52	775.00	1250	311.1	90	104.73	37.48	49.40	32.06	82.75	87.84	1.32	1.16	Mg-HCO3
129	Beehar	Rath	8.47	620.00	1000	292.8	72	77.70	19.95	32.60	62.12	62.02	52.25	1.26	0.89	Mg-HCO3
130	Barel	Rath	8.14	430.28	694	439.2	0	16.89	3.21	4.00	60.12	38.89	30.46	1.00	0.94	Mg-HCO3
131	Muskhera Khurd	Rath	8.11	579.08	934	475.8	0	54.05	14.10	24.40	62.12	47.41	50.74	1.11	0.79	Mg-HCO3

132	Bakrai	Rath	8.6	461.90	745	231.8	60	50.68	8.10	20.50	30.06	48.66	36.93	1.06	0.76	Mg-HCO3
133	Noranga	Rath	7.98	399.90	645	390.4	0	16.89	3.00	6.80	42.08	32.82	47.40	1.27	0.62	Mg-HCO3
134	Majhgawan	Rath	7.93	270.94	437	250.1	0	10.14	0.00	9.20	26.05	24.32	38.68	0.87	0.78	Mg-HCO3
135	Tooka	Rath	7.78	442.06	713	359.9	0	43.92	27.14	43.20	56.11	48.63	25.71	9.45	1.18	Mg-HCO3
136	Rath	Rath	7.93	1150.72	1856	378.2	0	334.46	118.15	33.40	38.08	46.22	303.95	3.74	0.83	Na-Cl
137	Chhibouli	Sarila	7.93	1150.72	1856	378.2	0	334.46	118.15	33.40	38.08	46.22	303.95	3.74	0.83	Na-HCO3
138	Rajamau	Sarila	8.39	510.26	823	408.7	0	13.51	17.23	13.40	10.02	15.82	119.20	0.48	1.33	Mg-HCO3
139	Dhauhal Buzurg	Sarila	7.88	334.80	540	292.8	0	23.65	4.85	9.50	34.07	14.57	52.89	0.79	0.67	Na-HCO3
140	Devkhuri	Sarila	8.63	917.60	1480	573.4	72	43.92	73.80	10.20	4.01	19.48	287.25	0.94	1.61	Mixed
141	Barkheda	Sarila	8.06	581.56	938	427.0	0	47.30	15.05	21.40	18.04	38.94	96.32	0.64	1.00	Na-HCO3
142	Bilpur	Sarila	8.58	852.50	1375	695.4	66	23.65	14.56	13.30	2.00	14.61	281.43	0.61	1.70	Na-Cl
143	Pachkhura	Sarila	7.98	2151.40	3470	372.1	0	628.38	323.20	3.20	50.10	57.16	474.30	2.95	1.43	Mixed
144	Kadoura	Sarila	8.37	437.10	705	347.7	30	13.51	8.72	9.90	10.02	29.21	88.42	0.80	0.87	Mg-HCO3
145	Harsundi	Sarila	7.96	314.96	508	237.9	0	16.89	1.37	5.40	44.09	18.21	16.80	0.70	0.77	Mg-HCO3
146	Bargawan	Sarila	8.03	287.68	464	207.4	0	16.89	6.40	3.80	30.06	15.79	25.18	0.86	0.66	Mg-HCO3
147	Sarila	Sarila	7.86	2523.40	4070	372.1	0	817.57	401.00	114.23	36.07	75.44	641.00	4.23	1.32	Na-Cl
148	Khera Silajit	Sarila	7.94	405.48	654	335.5	0	13.51	1.64	5.40	38.08	18.22	52.84	0.59	0.89	Mg-HCO3
149	Dhagwan	Sarila	7.86	406.72	656	384.3	0	13.51	3.31	6.90	30.06	23.10	74.16	0.72	0.93	Mg-HCO3
150	Baukhar	Sarila	7.81	432.76	698	378.2	0	16.89	1.65	19.90	32.06	37.70	54.85	0.99	0.65	Mg-HCO3
151	Jitakiri Danda	Sarila	7.82	377.58	609	341.6	0	16.89	0.00	7.20	34.07	27.96	52.40	0.83	0.71	Mg-HCO3
152	Chandaut	Sarila	7.99	405.48	654	341.6	0	20.27	6.59	4.30	24.05	25.54	74.70	1.56	0.67	Mg-HCO3
153	Indrapura	Sarila	8.02	313.10	505	244.0	0	16.89	10.49	1.10	32.06	15.79	49.65	1.10	0.59	Mg-HCO3
154	Ghutakwara	Sarila	7.96	415.40	670	384.3	0	10.14	0.80	1.80	24.05	18.23	85.47	0.81	0.86	Na-HCO3
155	Jariya	Sarila	7.76	478.64	772	414.8	0	27.03	10.53	19.30	54.11	27.94	64.62	0.73	0.73	Mg-HCO3
156	Kariyari	Sarila	7.82	426.56	688	305.0	0	57.43	9.89	5.40	50.10	12.11	63.87	1.41	0.83	Mg-HCO3
157	Mangrol	Sarila	7.95	383.16	618	329.4	0	20.27	2.60	8.10	34.07	21.87	59.16	0.77	0.86	Mg-HCO3
158	Parchha	Sarila	8.15	512.74	827	408.7	0	27.03	10.67	21.80	24.05	14.58	114.56	0.58	1.59	Na-HCO3
159	Puraini	Sarila	8.12	424.08	684	359.9	0	13.51	0.95	26.20	20.04	32.85	66.53	0.62	1.10	Mg-HCO3
160	Khandaut	Sarila	8.03	538.78	869	494.1	0	27.03	13.81	4.30	26.05	30.41	108.52	0.89	0.81	Mixed
161	Jalalpur	Sarila	8.08	614.42	991	481.9	0	43.92	27.72	31.60	22.04	30.41	143.98	0.78	0.84	Mixed

HCF* = Hydrochemical Facies

All values in mg/l except for pH and EC at 25°C in µS/cm

ANNEXURE – 3
(TRACE METALS DATA OF UNCONFINED AQUIFER)

Sl. No.	Location	Block	Cr	Cu	Fe	Mn	Zn	As
1	Terha	Sumerpur	0.003	0.008	1.64	0.011	0.267	BDL
2	Mihuna	Sumerpur	BDL	BDL	0.33	0.01	1.05	BDL
3	Sumerpur	Sumerpur	0.003	BDL	0.3	0.003	0.29	BDL
4	Ingohta	Sumerpur	0.003	BDL	0.497	0.003	0.85	BDL
5	Nadehra	Sumerpur	0.002	0.008	1.99	0.015	0.29	BDL
6	Dhanpura (Kalla)	Sumerpur	BDL	BDL	0.497	0.004	0.08	BDL
7	Ujnedi	Sumerpur	0.004	0.006	3.06	0.062	2.37	BDL
8	Chandulee Teer	Sumerpur	0.002	0.007	0.28	0.002	0.054	BDL
9	Aunta	Gohand	BDL	BDL	0.094	BDL	0.163	BDL
10	Pawai	Gohand	BDL	BDL	0.235	0.008	0.41	BDL
11	Jarakhar	Gohand	0.004	0.003	2.1	0.027	0.78	BDL
12	Bilgaon	Gohand	0.004	0.002	0.276	0.002	0.26	BDL
13	Churha	Gohand	0.004	0.005	0.636	0.004	0.553	BDL
14	Magrauth	Gohand	0.003	0.002	0.611	0.003	0.166	BDL
15	Simra	Kurara	0.002	0.002	1.3	BDL	0.085	BDL
16	Kusmara	Kurara	0.007	0.004	5.01	0.021	0.289	BDL
17	Raghwa	Kurara	0.002	0.002	1.71	0.012	0.459	BDL
18	Sikodi	Kurara	BDL	0.002	0.42	0.004	0.534	BDL
19	Jalla	Kurara	BDL	BDL	1.875	0.474	0.152	BDL
20	Kurara	Kurara	BDL	BDL	0.33	0.004	0.055	BDL
21	Sisolar	Maudaha	0.006	0.004	0.91	0.009	0.586	BDL
22	Chahani Par	Maudaha	0.011	BDL	0.85	0.004	0.247	BDL
23	Tikri Buzurg	Maudaha	0.002	0.0098	0.385	0.019	0.563	BDL
24	Bhainsta	Maudaha	0.002	0.004	1.75	0.019	9.48	BDL
25	Bhawani	Maudaha	0.002	BDL	2.49	0.042	2.43	BDL
26	Bhamaura	Maudaha	0.002	BDL	8.452	0.043	BDL	BDL
27	Baherela	Maudaha	0.003	0.01	0.82	0.006	0.246	BDL
28	Silauli	Maudaha	0.003	0.002	0.833	0.006	0.21	BDL
29	Bharsawan	Maudaha	0.003	BDL	1.116	0.01	BDL	BDL
30	Masgawan	Maudaha	0.003	0.002	2.13	0.012	0.289	BDL
31	Para	Maudaha	BDL	0.002	0.22	0.002	BDL	BDL
32	Kunethta	Maudaha	0.003	BDL	0.866	0.013	BDL	BDL
33	Binawar	Muskara	0.005	0.002	0.46	0.009	2.28	BDL
34	Neoriya	Muskara	BDL	0.002	0.52	0.009	0.24	BDL
35	Muskeda	Muskara	0.007	0.007	0.44	0.002	0.389	BDL
36	Khandehi Lodhan	Muskara	0.007	BDL	1.06	0.007	0.181	BDL
37	Bibhuni	Muskara	0.004	BDL	0.122	BDL	0.119	BDL
38	Teehar	Muskara	0.006	BDL	0.176	BDL	BDL	BDL

39	Mihuna	Muskara	0.008	0.002	0.287	0.002	BDL	BDL
40	Gundela	Muskara	BDL	0.003	0.388	0.003	0.1	BDL
41	Gohani Rath	Rath	0.002	0.002	0.25	0.002	0.214	BDL
42	Mawai	Rath	0.005	BDL	0.281	0.002	BDL	BDL
43	Basela	Rath	BDL	BDL	0.273	0.004	0.19	BDL
44	Muskhera Khurd	Rath	0.004	0.002	0.38	0.002	0.46	BDL
45	Majhgawan	Rath	0.004	BDL	0.189	BDL	0.064	BDL
46	Rath	Rath	BDL	0.002	0.6	0.006	BDL	BDL
47	Dhauhal Buzurg	Sarila	BDL	BDL	0.056	0.003	0.92	BDL
48	Bilpur	Sarila	BDL	BDL	0.18	0.006	1.13	BDL
49	Harsundi	Sarila	BDL	BDL	0.42	0.003	BDL	BDL
50	Khera Silajit	Sarila	0.003	0.009	0.61	0.004	0.58	BDL
51	Jitakiri Danda	Sarila	0.005	0.005	0.98	0.004	0.188	BDL
52	Ghutakwara	Sarila	0.003	0.006	0.28	0.002	0.13	BDL
53	Mangrol	Sarila	0.004	0.83	0.005	0.5	0.002	BDL
54	Khandaut	Sarila	0.004	BDL	0.44	0.003	0.32	BDL

All values in mg/l.

ANNEXURE – 4
(BASIC GW QUALITY DATA OF DEEPER AQUIFER)

Sl. No.	Location	Block	EC	pH	CO_3	HCO_3	Cl	NO_3	SO4	F	Ca	Mg	Na	K	HCF*
1	Jhalla	Kurara	1370	7.59	0	598	99	11	0	0.3	84	36	145	1.5	Mg-HCO3
2	Sarsai	Kurara	990	7.79	0	524	28	5.6	0	0.96	36	41	102	1.1	Mg-HCO3
3	Kurara Nagar	Kurara	940	7.45	0	488	21	6.1	0	0.43	60	36	65	1.5	Mg-HCO3
4	Banki	Sumerpur	920	7.6	0	500	28	10	32	0.08	32	49	97	1	Mg-HCO3
5	Jhalokhar	Kurara	900	7.82	0	439	35	4	46	0.7	36	36	101	2	Mg-HCO3
6	Harsundi	Sarila	460	7.8	0	244	43	3	30	0.36	48	27	29	1	Mg-HCO3
7	Kariyari	Gohand	2620	7.43	0	403	596	2	343	0.41	28	102	478	2	Na-Cl
8	Jharia Tilla	Sarila	900	8.4	18	421	43	3.1	7	0.6	36	34	100	1	Mg-HCO3
9	Chandpurwa	Sumerpur	836	7.4	0	345	45	0	60	0.2	40	38	90	0	Mg-HCO3
10	Neria	Muskara	1395	7.3	0	780	65	0	56	0.4	24	62	216	11	Mixed
11	Sarauli Khurd	Sumerpur	1115	7.55	0	583	34	0	69	0.2	62	33	125	1.6	Mg-HCO3
12	Sasa Buzurg	Sumerpur	450	7.9	0	601	16	0	0	0	10	33	86	2.5	Na-HCO3/Mixed

HCF* = Hydrochemical Facies

All values in mg/l except for pH and EC at 25°C in µS/cm

ANNEXURE – 5
(STATISTICAL DATA OF BLOCK WISE IRRIGATION)

Sl. No.	Block	Percentage of gross irrigated area from net irrigated area		
		2010 – 2011	**2016 – 2017**	**2017 – 2018**
1	Kurara	101.50	101.52	101.94
2	Sumerpur	98.80	101.12	60.26
3	Sarila	95.40	103.06	104.63
4	Gohand	98.10	107.45	101.96
5	Rath	102.20	105.71	101.96
6	Muskara	104.90	102.65	101.96
7	Maudaha	101.40	101.76	100.88

Sl. No.	Block	Percentage of gross sown area from net sown area		
		2010 – 2011	**2016 – 2017**	**2017 – 2018**
1	Kurara	115.80	133.96	140.70
2	Sumerpur	121.60	123.39	120.88
3	Sarila	108.60	135.56	146.72
4	Gohand	129.20	135.57	130.33
5	Rath	143.10	169.03	153.27
6	Muskara	126.50	133.42	129.00
7	Maudaha	112.20	113.43	119.26

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